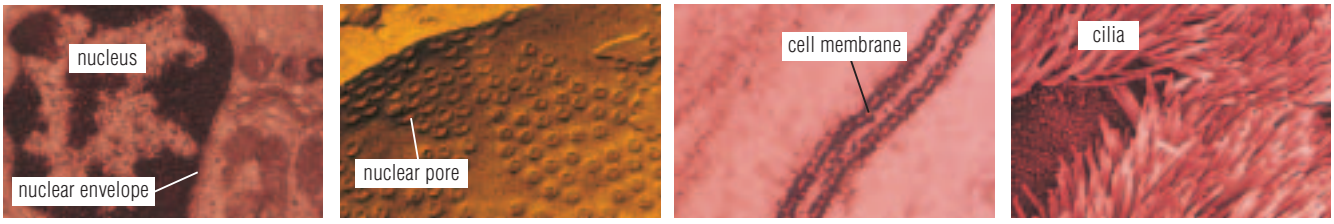
reSEARCH

Investigate recent developments in microscopy. Begin your search at www.pearsoned.ca/school/science10

structural arrangements, such as the two layers making up the cell membrane, that may have been suggested by experiment but had never been seen before. Scientists were able to view cells at magnifications of 500 000 times and more. Figure C1.23 shows some of the detail available in electron micrographs.

One of the drawbacks of the TEM is the difficulty of building up a three-dimensional picture of the cell from very thin sections. The detail is impressive but the area covered by each image is very small. Also, the specimens are fixed, and therefore no longer living, and the microscope must be operated in a vacuum. Recently, a form of the SEM has been developed that allows the use of live material.

Each type of microscopy has its important place in cell research. Depending on the investigation, biologists may use different types of microscopes, staining technologies, and contrast enhancing technologies to explore cell structure and function.



(a) A transmission electron micrograph of a white blood cell shows detail of the nucleus and nuclear envelope, and mitochondria in the cytoplasm. (approx. ×49 000)

(b) A transmission electron micrograph prepared by freeze fracture which splits the structure into two parts, shows detail of the pores in the nuclear envelope. (approx. ×90 000)

(c) In a transmission electron micrograph, the cell membrane can be seen as two thin dark lines separated by a clear layer in two adjacent cells. (approx. ×25 000)

(d) In a scanning electron micrograph, the surface features of cells can be seen, as in the cilia shown here. (approx. ×11 000)

FIGURE C1.23 Transmission and scanning electron micrographs show different detail of cells.

C1.3 Check and Reflect

Knowledge

1. What are the advantages and disadvantages of using a light microscope?
2. Explain why investigators need to stain cells.
3. When would there be a need for using an electron microscope?
4. Describe ways in which a confocal microscope works differently from the light microscope you use in your science lab.
5. What is fluorescence microscopy? Give an example of a study using fluorescence microscopy.
6. Describe similarities in the ways in which a light microscope and a TEM work.

Applications

7. Choose two advances in imaging technology and explain how they have led directly to a new understanding of cell structure and function.
8. Create a poster or PowerPoint presentation showing a variety of microscopes and/or techniques. Explain why each would be useful for a particular study.

C1.4 Cell Research at the Molecular Level

As a result of new technology, research on cells has led to major breakthroughs in medicine and industry. There are many areas in which research is now at the molecular level. The recently developed Scanning Tunnelling Microscope (STM) and Atomic Force Microscope (AFM) are able to reveal even smaller structures than the transmission or scanning electron microscopes can. Scanning tunnelling microscopes and atomic force microscopes allow scientists to produce images of molecules, and, therefore, to improve their understanding of the structure and function of molecules within the cell. New interpretations are possible when observations made by earlier scientists are combined with modern chemical and computer methods. Figure C1.24 contrasts (a) a model of DNA superimposed on an actual cell with (b) an STM image of DNA in which the yellow peaks represent the ridges of the DNA helix.

infoBIT

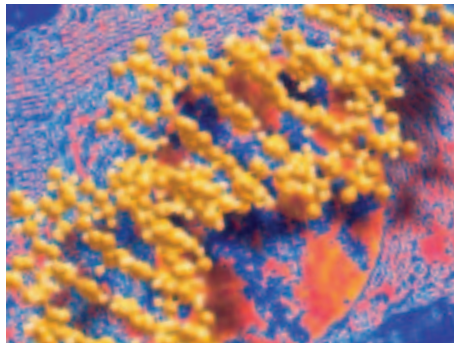
Dr. Michael Ellison at the University of Alberta is working on "Project Cybercell," a virtual cell created with computers and mass spectrometers. The purpose of Cybercell is to study life at the molecular level, using what is known about the 4000 proteins of the *E. coli* bacterium. Cybercell will exist in a virtual environment that will allow Dr. Ellison and his colleagues to manipulate and predict the ways in which cells can grow, divide, adapt, and evolve.

Gene Mapping

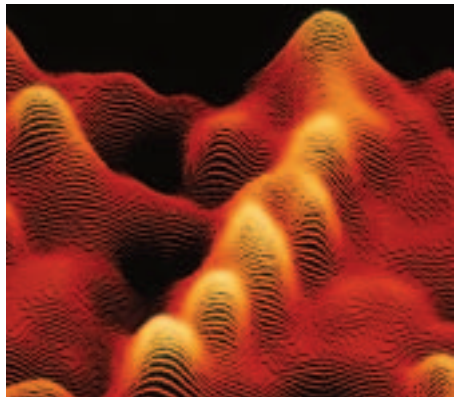
In less than 200 years since Brown observed the nucleus in the orchid, scientists have made great progress in understanding the cell. Microscopists in the 19th century saw chromosomes in the nuclei of cells. Geneticists showed that material in the chromosomes was associated with patterns of inheritance. Chemists, biochemists, and microbiologists showed that the genetic material in the chromosomes was DNA and that DNA has a structure that enables it to direct all other activities in the cell. Improvements in techniques of molecular biology allowed mapping of the human genome to begin. In 2001, a draft of the complete genetic map of humans was published in the results of the Human Genome Project.

Gene mapping of many plant and animal species is progressing. The mapping of DNA sequences in genes involves many techniques, including breaking cells down to release their DNA, using chemical techniques to make many copies of the DNA, and finding the sequence of chemical subunits through computer analysis. DNA analysis and gene mapping open up our understanding of the way different parts of the genetic material work together. This knowledge may one day allow scientists to manage disease-causing abnormalities; for example, cancer research is benefiting from a deeper understanding of the molecular functioning of the cell.

Gene mapping of crop plants may result in new varieties that are resistant to pests or can thrive in drought conditions. However, concerns have been raised about resistance being incorporated into weed species as well. Ethical issues have also been raised about ways in which knowledge and procedures related to DNA and gene mapping may be used in the future. The technology available sets limits to the science that can be done, and in a similar way, the needs and issues in society must provide guidelines for how science is conducted.



(a) Computer artwork of a DNA molecule superimposed on a TEM of a human cell



(b) An STM image of a double-stranded DNA molecule (approx. ×2 000 000)

FIGURE C1.24 The genetic material can be represented in several different ways.

Activity C5

QuickLab

Extracting DNA from Pea Soup

In animal and plant cells, the genetic material, DNA, is found in the nuclei. The DNA is arranged into structures called chromosomes in which it is bound to protein molecules. The first step in gene mapping is to extract the DNA from cells. This is a simpler process than you might expect.

Purpose

To extract DNA, the genetic material of life, from pea soup

Materials and Equipment

- 50 mL dried green split peas
- 250 mL water
- 250 mL 90% rubbing alcohol chilled in a freezer and kept on ice
- salt
- meat tenderizer
- liquid dishwashing detergent
- 250-mL beaker
- blender
- strainer
- tablespoon or 25-mL measuring spoon
- 25 × 200 mm test tube
- dissecting probe, crochet hook, or bamboo skewer

Procedure

CAUTION: Wash your hands at the end of the lab activity.

1. Place approximately 50 mL of dried green split peas, a pinch of salt, and about 100 mL of water in a blender. Blend for about 20 s. Blending helps to separate the pea cells.
2. Pour the mixture through a strainer into a beaker. Discard the material left in the strainer. Measure the amount in the beaker and add about one-sixth of that amount of water to the beaker.
3. Add about 1 tablespoon of liquid dishwashing detergent to the beaker and mix. Allow the mixture to sit for 10 min.
4. Pour the mixture into the 25 × 200 mm test tube until about one-third full and add a pinch of meat tenderizer to the test tube.
5. Slowly and carefully, pour chilled rubbing alcohol down the side of the test tube to form a clear layer on the top of the mixture. Use about the same volume of alcohol as the volume of pea mixture in the test tube.
6. With a dissecting probe, crochet hook, or bamboo skewer, gently pull out the stringy material that forms in the alcohol layer. Spool this material onto the holder with a twirling motion. This is DNA from the green split peas!

Questions

1. Why do you think you added detergent in step 3?
2. The meat tenderizer is a protein called an enzyme that cuts other proteins away from the DNA. What does a meat tenderizer do when you use it on steak?
3. Write the recipe for extracting DNA from liver or onion cells.

*info*BIT

A group of diseases appear to be linked not to bacteria or viruses but to specific proteins called "prions" that act as infectious agents. These proteins spread spongiform encephalopathies, which produce large vacuoles or empty pockets in the brain. Bovine spongiform encephalopathy (BSE) results from prion infection and is commonly known as "mad cow disease."

Cell Communication

An **open system** is one that must interact with its environment to maintain its existence. Cells are efficient open systems able to carry on all of the life processes. To function efficiently, cells must interact with their environment and with each other. For cell-to-cell communication, messenger molecules from other cells travel through the bloodstream and attach to specialized molecules on the surface of the target cell. These molecules, known as receptors, may change in shape and trigger a chain reaction to carry the message to the proper location inside the cell. You might think of how the structure of your front door key, fitting into the shape of the door lock, allows you to pass the barrier of your front door and bring in information about your day to your family inside the house. Techniques that show binding of substances to cell membranes, such as the fluorescent antibody technique, allow diagnosis of diseases carried by viruses, bacteria, and protozoans, as well as diseases of the immune system.

Activity C6

Decision-Making Investigation

Student Reference 4, 9

Required Skills
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Gene Mapping: Opportunity or Risk?

The Issue

How would you weigh the risks and benefits associated with one type of cell research at the molecular level?

Background Information

In April 2002, a Swiss agrochemical company announced that, in collaboration with Chinese researchers, they had determined the gene sequences of two commonly grown rice species. Canadian physicist Gane Ka-Shu Wong, working at the University of Washington, was involved in this ground-breaking discovery. The importance of mapping the genes of crop plants should not be underestimated. There are major agricultural and societal implications. For instance, with approximately 50 000 genes in rice (as compared to 30 000–40 000 in humans), plant breeders may be able to create "designer" strains. They may be able to produce plants that are drought or pest resistant. Since rice is very vulnerable to environmental factors, especially drought, resistant strains would ensure better crops even in poor conditions. Farmers would be able to plant crops that produce higher yields on less land. We may be able to develop grains that are of higher nutritional value than those that are currently grown. When you consider the numbers of people worldwide who consume and depend on rice as a main staple food, the possibilities for plant breeding and agriculture are enormous. Rice is closely related to other cereal grains including wheat, barley, and corn. Cracking the genetic code for these plants cannot be far off.

Some scientists are concerned about using information on the genetic make-up of crop plants to selectively modify or change species. They argue that concentrating on only a few varieties of rice, for instance, will reduce diversity and impact ecosystems. New diseases or environmental conditions could wipe out all of the monoculture crops. Examples of this risk have been seen in monocultures produced by older forms of plant breeding; for example, much of the corn crop in the United States was wiped out by a blight-causing fungus in 1970. They also suggest that farmers may be forced to pay inflated prices to obtain the genetically modified seed in order to remain competitive. Some argue that we still do not know if there are significant health concerns to be considered when dealing with genetically modified crops. The possibility that the attractive qualities of disease resistance or environmental tolerance could be transferred into weed species remains a concern.

Analyze and Evaluate

1. State a definition of a "risk" and a "benefit" as it pertains to the issue of cell research at the molecular level. Share your definitions with your classmates. Modify your definitions based on the discussion.
2. In chart form, identify the risks and benefits of gene mapping of crop plants. Be sure that the ideas you list fit with your definitions of "risk" and "benefit."
3. Susan R. McCouch, an associate professor of plant breeding at Cornell University, stated in a press release in 1996 that "Land mass is actually shrinking in Asia, and as a society, we've increased rice yields per acre about as much as we could. We can't increase the land, so we have to do something. Fertilization is no longer an effective way to boost yield—it's plateaued. So, instead of boosting land mass—which we can't do—we're manipulating the plant's genetics." (Reference: www.news.cornell.edu/releases/Nov96/Rice.Nature.bpf.html) Use electronic and print resources to research the current applications of gene mapping of crop plants in Canada and around the world. Begin your search at www.pearsoned.ca/school/science10.
4. There are many different perspectives surrounding the issue of gene mapping. Assume that you are chosen to represent one of these perspectives at an international conference on genome mapping. Identify the risks and benefits from the point of view of one of the following conference delegates, and present your views.
   - President of an agrochemical company
   - Traditional farmer
   - Organic farmer
   - United Nations Food and Agriculture Organization (FAO) representative
   - President of the Canadian Medical Association
   - Consumer of commercial and agricultural goods
   - Federal Agriculture Minister
   - Canadian International Development Agency (CIDA) representative

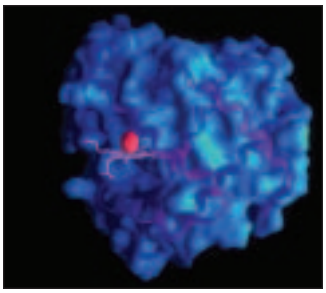


FIGURE C1.25 Computer-generated model of the protein myoglobin, the oxygen-storage compound in muscles, showing the binding site for oxygen

Three-Dimensional Structure of Molecules

Molecules inside the cell or on its surface often act as switches to control cell activity. The structure of a molecule, such as whether it is coiled or straight or whether it is made of repeated units, may determine how the molecule will function. **X-ray crystallography** uses X-rays, special sensors that analyze patterns of X-ray scattering, and computer technology to allow scientists to learn the details of molecular structure to help them understand how the molecules work. This technique was essential to studies that led to the model of the DNA molecule, and our understanding of how DNA functions in the cell. Researchers are now studying the three-dimensional shape of normally functioning and defective proteins to find the parts of the molecules that control the activity of the proteins. One of the first molecules to be studied this way was myoglobin, the protein that stores oxygen in muscles. Figure C1.25 shows a three-dimensional model of myoglobin.

Green Fluorescent Protein (GFP) Technology and Genetic Studies

Huntington's, Alzheimer's, and Parkinson's diseases are degenerative diseases of the nervous system. GFP technology, which was discussed on page 258, is being used in the study of these diseases at the molecular level. It is known that in affected individuals, abnormal proteins clump together and inhibit the normal functioning of cells. The use of GFP technology is allowing scientists to compare proteins in living cells of healthy tissue and in tissue that is affected by one of these diseases. In time, this information may lead to effective methods of treatment and change the lives of people living with these conditions.

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Investigate the types of technology used in studies of the three-dimensional structure of molecules. Begin your search at www.pearsoned.ca/school/science10

C1.4 Check and Reflect

Knowledge

1. Describe one example of cell research in industry or medicine.
2. List three of the technologies used in X-ray crystallography.
3. What is one advantage of using GFP technology in cell studies?

Application

4. Draw a chart like the one below in your notebook or journal and list the risks and benefits of DNA and gene mapping. Share your responses with a partner.

Risks	Benefits

Extensions

5. Take a stand for or against further research into the genome and indicate your reasoning, based on your list from question 4. Write a paragraph defending your position.
6. What additional information would you like to have on the issue of gene mapping that would help to make the issue clearer?
7. Using the Internet, report on new knowledge or treatments in an area of medicine or industry that have resulted from cell research.
8. Molecular research has enhanced an area of science called biochemistry. Find out about the types of job opportunities in this field.

Section Review

Knowledge

1. Describe the method of inquiry used by Aristotle and compare it with the methods used by other philosophers of his time.
2. The microscope invented by Hans and Zacharias Janssen is considered to be a "compound microscope." Why?
3. State what you consider to be Robert Hooke's contribution to microscopy and the understanding of the cell.
4. Briefly describe the advantages of laparoscopic surgery and how it depends on microscopy.
5. Explain what is meant by a "control" in an experiment.
6. Sketch the parts of Pasteur's experiment on spontaneous generation. Explain how this experiment provides evidence against spontaneous generation.
7. What similarities and differences did you see among pond water organisms?
8. Describe how to make a wet mount slide.
9. State the three main points of the cell theory and attribute each one to the scientist(s) responsible.
10. Outline two methods for improving the contrast in a specimen viewed under the microscope.
11. What are the advantages of confocal laser technology applied to microscopy?
12. What is X-ray crystallography? How is this technique used to advance cell research?
13. What is GFP and how is it used in genetic studies?

Applications

14. A microscope has a low-power magnification of 100×, a high-power magnification of 450×, and a low-power field diameter of 1800 µm. What is the high-power field diameter in micrometres?
15. If the minimum image size the human eye can detect is 0.1 mm, what is the minimum magnification needed to make an object measuring 1 µm visible? Explain how you determine your answer.
16. You have determined the field size of the low- and high-power objective lenses. How could you calculate the field diameter of the medium-power lens? Include an equation in your answer.
17. What important lesson about canning foods can be drawn from the experiments to disprove spontaneous generation?
18. You have just isolated a new microbe from your aquarium. Which type of microscopy would be used to determine:
    a) its movement?
    b) if this specific strain is present in other aquariums?
    c) if there are internal sub-structures?
    d) if there are special surface structures on the cell?
19. How might your life be different if the microscope had never been invented?
20. Identify the most significant thing you learned from this section, and one area that you would like to know more about.

Extensions

21. Using your diagrams of the organisms observed in the pond water, and electronic and print resources, try to identify each microbe.
22. Although the design of the compound light microscope in use today is essentially the same as that developed 350 years ago, Hooke would be surprised at the detail that we can now see. List advances in technology and techniques that have improved the images seen through the light microscope. Explain how each advance has led to an increase in our understanding of the cell.
23. Find a current newspaper or magazine article on an area of cellular research. Paste it in your notebook and describe the risks and benefits associated with this area of research.

UNIT C

2.0

Living systems are dependent upon the functioning of cell structures and organelles.

Key Concepts

In this section, you will learn about the following key concepts:

- cellular structures and functions and technological applications
- active and passive transport of matter
- relationship between cell size and shape, and surface area to volume ratio
- use of explanatory and visual models in science

Learning Outcomes

When you have completed this section, you will be able to:

- compare passive transport of matter by diffusion and osmosis with active transport in terms of the particle model of matter, concentration gradients, equilibrium, and protein carrier molecules
- use models to explain and visualize complex processes like diffusion and osmosis, endo- and exocytosis, and the role of cell membrane in these processes
- describe the cell as a functioning open system that acquires nutrients, excretes waste, and exchanges matter and energy
- identify the structure and describe, in general terms, the function of the cell membrane, nucleus, lysosome, vacuole, mitochondrion, endoplasmic reticulum, Golgi apparatus, ribosomes, chloroplast, and cell wall, where present, of plant and animal cells
- compare the structure, chemical composition, and function of plant and animal cells, and describe the complementary nature of the structure and function of plant and animal cells
- describe the role of the cell membrane in maintaining equilibrium while exchanging matter
- describe how knowledge about semi-permeable membranes, diffusion, and osmosis is applied
- describe cell size and shape as they relate to surface area to volume ratio, and explain how that ratio limits cell size

FIGURE C2.1 Medieval cities were enclosed by walls to limit entry and exit of people and materials.

In an open system such as the cell in which matter and energy are exchanged with the environment, interaction with the surroundings is crucial to provide needed materials, produce what is required, and ship out any excess. Consider the analogy of a medieval town or Old West fort that had enclosures for protection. Here, the enclosures were built so that threats would be kept out, but needed supplies and materials could get in. In addition, anything produced inside the enclosure could be transported outside the walls. Contrast this with a closed system or with an isolated system in which there is no interaction with the outside.

Today's towns and cities do not have elaborate enclosures, but they continue to operate as open systems in much the same way. City Hall is the hub of a town's activities where decisions are made that will affect the growth, economy, and living conditions of the town. Factories and processing plants depend on raw materials brought in from mining, drilling, or agriculture. The products may be in the form of food or materials to support the growth and operation of the community. Some products may be in greater supply than the town needs and these are shipped to other places. Other products may be brought in from other communities. The movement of substances into, around, and out of the town is accomplished using trucks, trains, airplanes, or other means. Services like hospitals, grocery stores, schools, police and fire departments, and sanitary dumps are all necessary parts of the town. Sometimes, it may be necessary to bring in specialists from the outside. The success of the town is based on its ability to maintain a positive environment to sustain itself. The cell is an open system much like the town described here. The components of the cell are called **organelles**, meaning little organs, and the functioning of these structures maintains the life processes of the cell.

This section considers the cell organelles and how they carry out the functions necessary for the cell to survive. Models will be used to represent and explain these processes and some of their applications in medicine and industry.

C2.1 The Cell as an Efficient, Open System

Any efficient open **system** has many parts that work together for a particular goal. Each part has its own function. Cells, the basic units of life, maintain the life processes within specialized structures called organelles, each with its own function to perform. Cells are highly efficient, open systems that are able to exchange matter and energy with their surroundings. Cells carry on all of the life processes including:

- intake of nutrients
- movement
- growth
- response to stimuli
- exchange of gases
- waste removal
- reproduction

A cell must work constantly to maintain a fine balance among the different life processes in order to be efficient and to conserve energy. A good starting point for understanding the functions of the cell is to identify the major structures involved in each of the cell's activities. Turn to page 270, Figure C2.10, to see diagrams that show the components of a typical animal cell and a typical plant cell. Table C2.1, below, provides photomicrographs of cell structures, as seen through the light and electron microscopes, and briefly describes their functions.

info BIT

In early microscopes the nucleus looked like a kernel or seed. Some single-celled organisms that exist without a nucleus are called *prokaryotes*. This word comes from the Latin *pro* meaning "before" and karyote, from the Greek *karyon* meaning "kernel"; it suggests that these organisms existed before structures such as the nucleus were formed.

TABLE C2.1 Cell Structures and Their Functions

Cell Structure and Function	Photomicrograph
The **cell membrane** is a protective barrier for the cell: allows the transport of needed materials into the cell and waste materials out; is important for cell interaction and communication, and for recognition of molecules.	
The **nucleus** is the organelle that contains DNA, the genetic material of the cell, and directs all cellular activities. The nucleus is surrounded by the nuclear envelope, which has pores to allow the transport of materials.	
The **cytoplasm** is a gel-like substance inside the cell membrane: contains the nutrients required by the cell to carry on the life processes. The organelles are suspended in the cytoplasm. The physical nature of the cytoplasm allows for the movement of organelles and molecules within the cell, referred to as **cytoplasmic streaming**.	

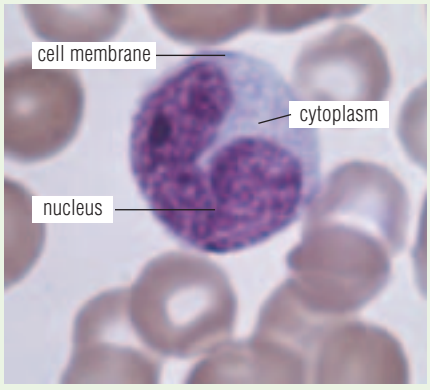
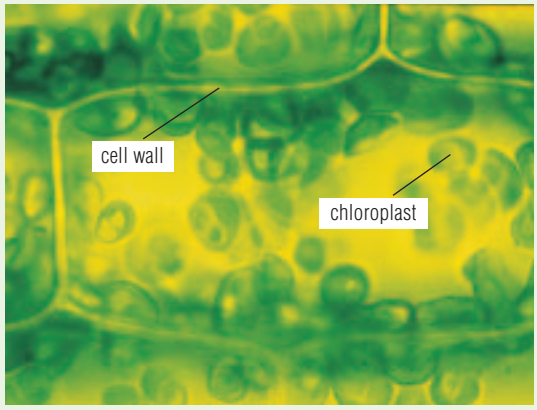
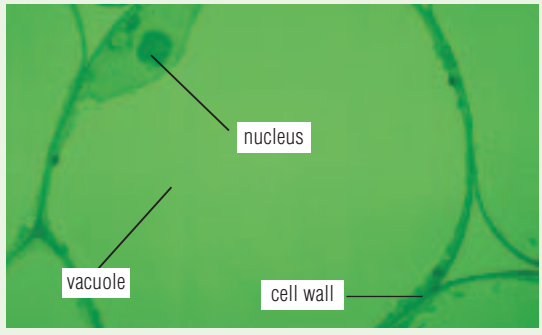
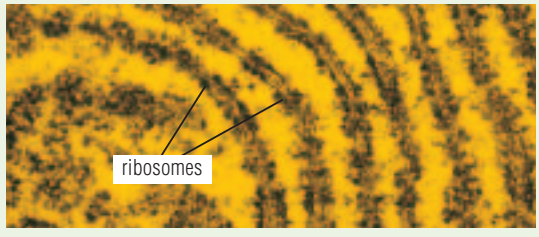
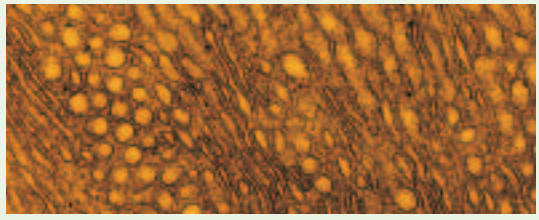
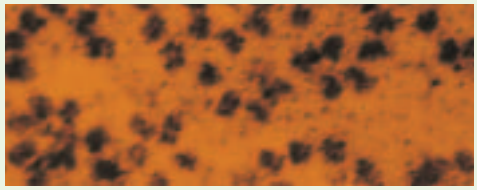
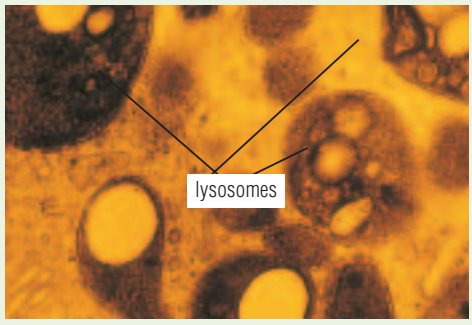
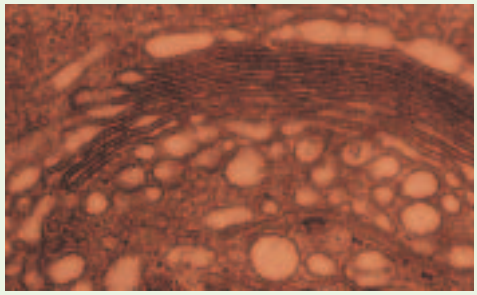
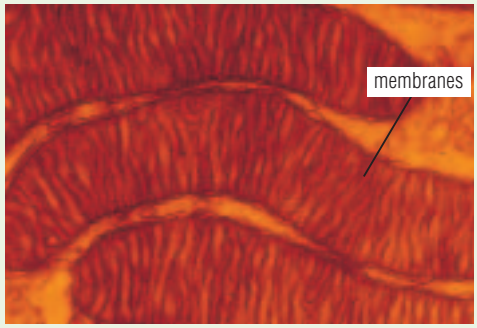


FIGURE C2.2 The cell membrane, nucleus, and cytoplasm in a human white blood cell seen through the light microscope. (approx. ×300)

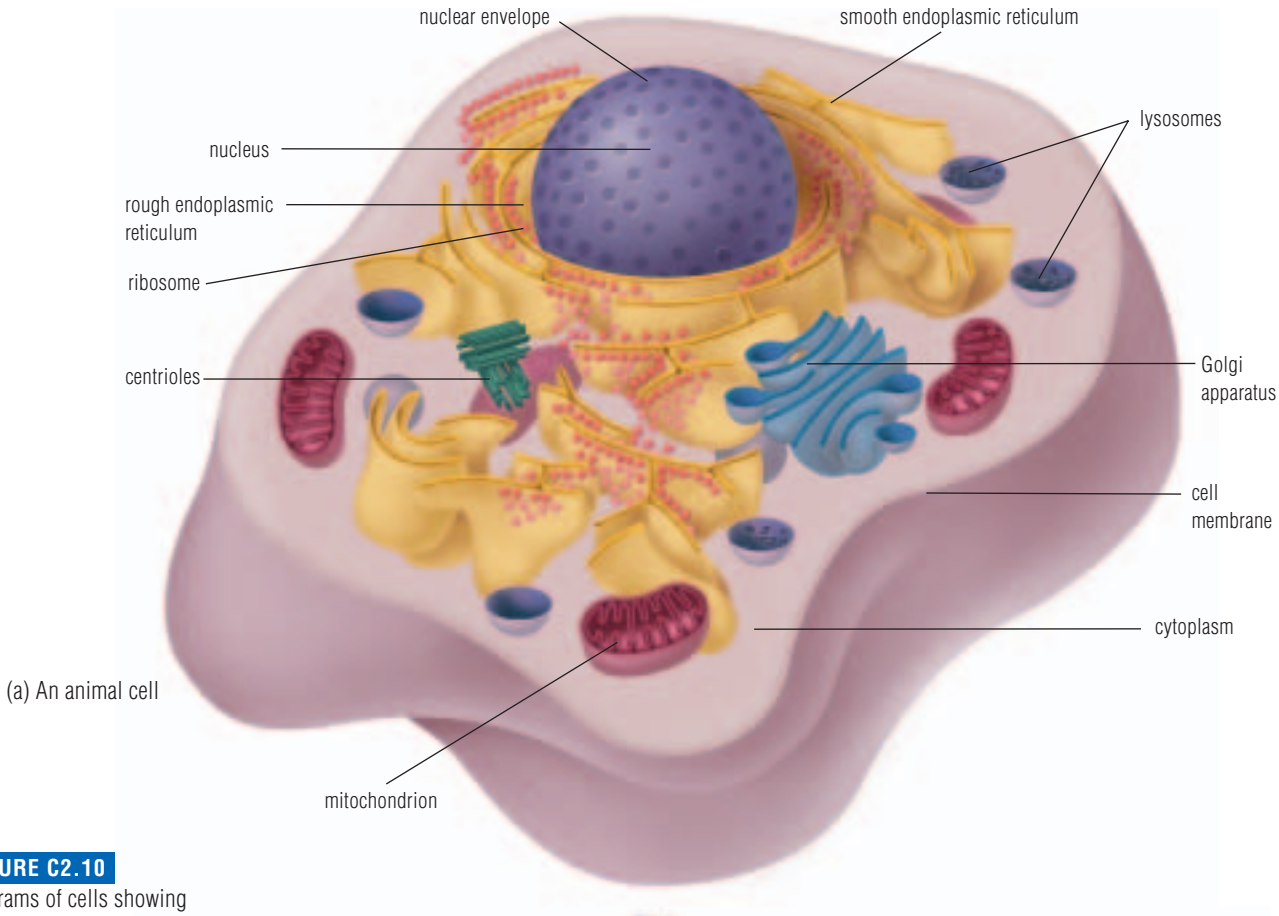
Cell Structure and Function	Photomicrograph
The cell wall is found in plants, bacteria, some **protists**, and fungi: the cell wall is a rigid frame around the cell that provides strength and support.	 **FIGURE C2.3** The cell wall and chloroplasts in a plant cell seen through the light microscope. (approx. ×2000)
Chloroplasts are found only in plants and some protists. They contain chlorophyll that produces a green colour; are the sites of photosynthesis, the process which uses energy from the Sun to convert carbon dioxide and water into sugars for the plant's use and storage. The equation for photosynthesis is: $6H_2O_{(l)} + 6CO_{2(g)} \xrightarrow{\text{chlorophyll + light}} C_6H_{12}O_{6(aq)} + 6O_{2(g)}$	
Vacuoles and **vesicles** are membrane-bound structures that serve to store nutrients, products of secretion, and fats, depending on the tissue type. In plants, the central vacuole stores water for the cell. In plant cells, when fluids enter, the central vacuole swells, increasing the **turgor pressure** and causing the cell to become firm or **turgid**. Vesicles transport substances throughout the cell.	 **FIGURE C2.4** Vacuoles may store materials or fluids. Transmission electron micrograph (approx. ×24 000)
The **endoplasmic reticulum** is a series of interconnected small tubes that branch from the nuclear envelope. Materials can be transported through these tubes. **Rough endoplasmic reticulum** has ribosomes attached to it and is associated with protein synthesis; **smooth endoplasmic reticulum** is associated with fat and oil production.	 **FIGURE C2.5** (a) Rough endoplasmic reticulum has ribosomes attached to it. Transmission electron micrograph (approx. ×95 000)  (b) Smooth endoplasmic reticulum does not have ribosomes. Transmission electron micrograph (approx. ×130 000)

All of the cell organelles, except the ribosomes, are enclosed by a membrane.

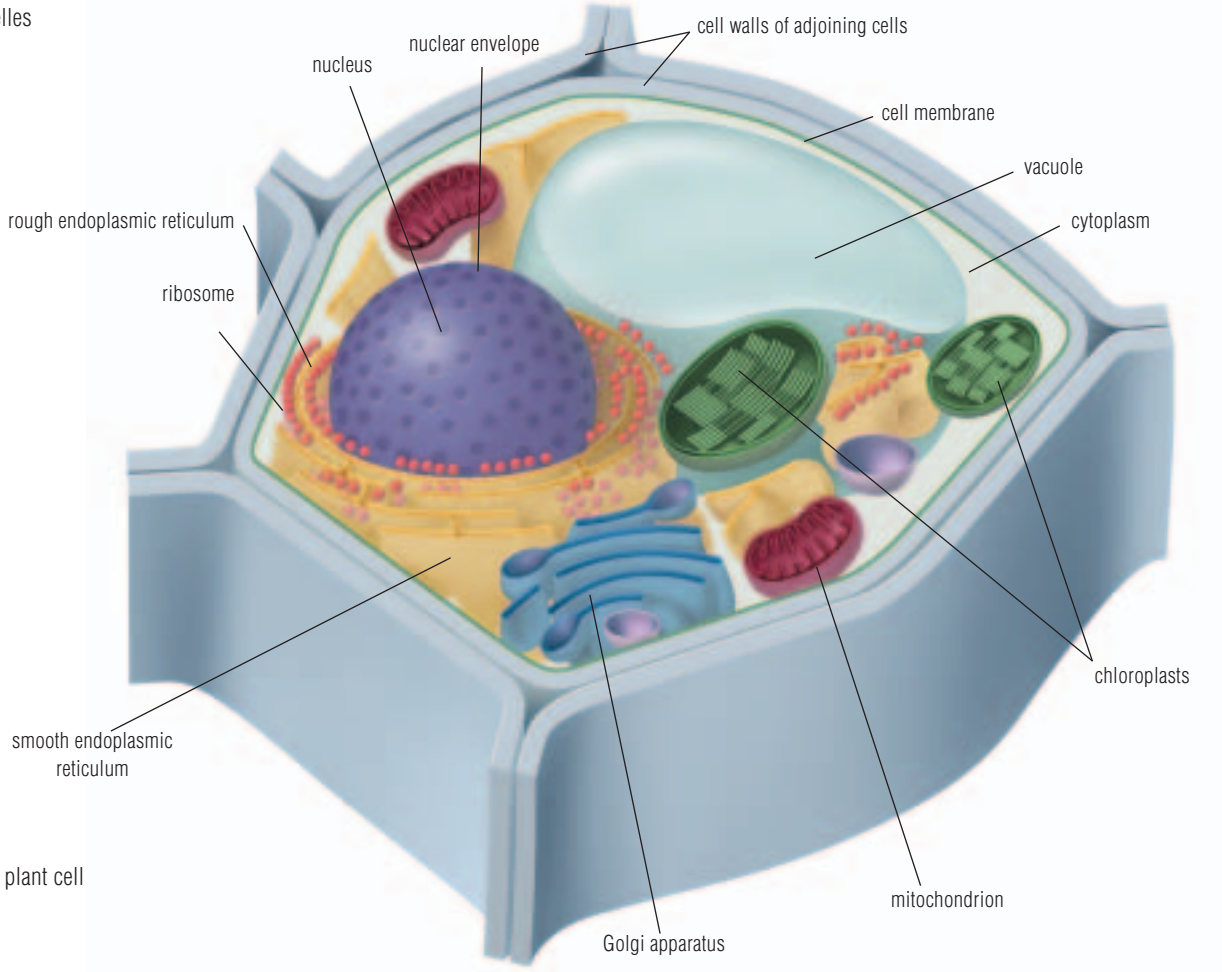
Cell Structure and Function	Photomicrograph
Ribosomes are dense-looking granules formed of two parts. They may be attached to the endoplasmic reticulum or free in the cytoplasm. Ribosomes are the sites where amino acids are assembled into proteins in the process of **protein synthesis.**	 **FIGURE C2.6** Whether free or attached, ribosomes are the sites of protein synthesis. Transmission electron micrograph (approx. ×340 000)
Lysosomes are membrane-bound sacs in the cell in which digestion can go on. The various roles of lysosomes include defence against invading bacteria, destruction of damaged cell organelles, and controlled digestion of certain tissues during development.	 **FIGURE C2.7** Lysosomes contain strong chemicals that digest molecules within cells. Transmission electron micrograph (approx. ×29 000)
The **Golgi apparatus** is composed of flat, disc-shaped sacs involved in secretion. The Golgi receives substances from the endoplasmic reticulum and packages them for transport out of the cell.	 **FIGURE C2.8** The Golgi apparatus modifies molecules and prepares them for transport. Transmission electron micrograph (approx. ×110 000)
Mitochondria are rod-like structures where reactions occur to convert chemical energy in sugars into energy the cell can use. This process is called **cellular respiration**. The chemical equation for cellular respiration is: $C_6H_{12}O_{6(aq)} + 6O_{2(g)} \longrightarrow 6CO_{2(g)} + 6H_2O_{(l)} + \text{energy}$	 **FIGURE C2.9** Mitochondria have an inner and an outer membrane and a liquid matrix. Transmission electron micrograph (approx. ×130 000)

info BIT

Severe diseases result when lysosomes cannot function properly because vesicles that should carry substances like proteins to the lysosomes get lost in transport. Dr. Vett Lloyd of Dalhousie University in Halifax, Nova Scotia, studies the problems that occur when vesicle transport does not happen normally. She uses *Drosophila melanogaster* (a small fly), which is a good animal model for conditions seen in humans, to better understand the role of vesicle transport in cells of the human body.



(a) An animal cell



(b) A plant cell

FIGURE C2.10
Diagrams of cells showing the organelles

Activity C7

Inquiry Lab

Student Reference 8

Required Skills
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Comparing Structures in Plant and Animal Cells

The Question

Are there differences between plant and animal cells that are observable through the light microscope?

The Hypothesis

State a hypothesis concerning the differences between plant and animal cells that you will be able to see through the light microscope.

Materials and Equipment

compound light microscope

prepared slides: plant and animal cells

CAUTION: To avoid cuts, use proper technique when handling the microscope and glass slides.

Procedure

1. Set up the compound light microscope. Refer to Student Reference 8: The Compound Light Microscope.
2. Observe the prepared slides of both animal cells and plant cells. Use the low-, medium-, and high-power objective lenses.
3. Draw and label one plant and one animal cell. Use the magnification where the whole cell is visible and the cell parts are clearest. Use the technique you learned in Activity C2 to estimate the actual size of the cells. For each diagram indicate the magnification and the scale of the drawing.

Analyzing and Interpreting

1. Make a chart of the cell structures that you were able to see in the animal cells and the plant cells.
2. Compare the following cell structures in animal and plant cells: cell membrane; nucleus; cytoplasm.
3. Describe the differences in the image you see when using the high-power objective lens instead of the low-power objective lens.

Forming Conclusions

4. Use your observations to reach conclusions about the differences between plant and animal cells that are visible through the light microscope.

Applying and Connecting

5. Suggest reasons why certain organelles shown in Figures C2.10(a) and C2.10(b) are not visible through the light microscope.
6. Use Table C2.1 and Figures C2.10(a) and C2.10(b) to review the structure and function of these cell organelles that you could not see through the light microscope.

In Activity C7, you would have observed that some of the cell organelles are visible when you use the compound light microscope, but some are not. The electron microscope provides images of these structures, and inferences can be made about their function. Figures C2.4–C2.9 on pages 268–269 show electron micrographs of the structures that cannot be seen in detail through a compound light microscope.

The Chemical Composition of Cell Structures

The major elements making up the structure of plant and animal cells are carbon, hydrogen, oxygen, and nitrogen. These are organized into four major organic compounds: **lipids** like fats and oils; **carbohydrates** such as sugars, starches, and cellulose; **protein**, for example, muscle fibre; and **nucleic acids**

reSEARCH

Lipids, carbohydrates, proteins, and nucleic acids are called the primary metabolic products of cells because all cells require these substances to live, grow, and reproduce. Cells also produce additional, or secondary, metabolites that may vary from cell to cell or from species to species depending on the organism. Find out the importance of secondary chemical substances in plants and some of the ways these substances are used by humans. Begin your search at www.pearsoned.ca/school/science10.

such as DNA, the genetic material. Water is the other major compound found in all plant and animal cells. Many other substances are dissolved in water, so we say that water is the **solvent** that provides the environment for all biological reactions inside and outside cells. In addition, there are substances called **trace elements** present in tiny amounts that are essential for the health of the cell. Magnesium (Mg), zinc (Zn), manganese (Mn), and iron (Fe) are examples of trace elements.

There are similarities and differences between plant and animal cells in terms of chemical composition. Similarities are:

- animal and plant cells have a cell membrane and an internal network of fibres, the **cytoskeleton**, made up of proteins and lipids;
- animal and plant cells have genetic material (DNA) made up of sugars, nitrogen bases, and phosphate.

Some of the differences are:

- animal cells have **centrioles**, which are involved in cell division; plant cells do not have centrioles.
- plant cells have a rigid cell wall made of cellulose, a type of carbohydrate, whereas animal cells do not have cell walls;
- plant cells contain a specialized chemical compound called **chlorophyll**, a pigment that makes photosynthesis possible;
- some animal cells have other specialized compounds; for example, hemoglobin in red blood cells and cholesterol in other cells;
- some plant cells store energy in the form of starch or oils, for example, cornstarch and canola oil; for energy storage, animal cells may contain glycogen, another form of carbohydrate, or lipids in the form of fats.
- plant cells have a large central vacuole; vacuoles and vesicles in animal cells tend to be small.

A Model of the Cell Membrane

The electron microscope has provided very detailed images of the cell membrane that allowed scientists to gain a better understanding of the role of the membrane in maintaining **equilibrium** or balance inside the cell. The cell needs to keep this equilibrium while allowing some substances in and keeping others out. The membrane, sometimes referred to as the **plasma membrane**, consists of a **phospholipid bilayer**. This is a double layer of lipids that each have a phosphate group attached. The phosphates face out into the watery fluids on either side of the membrane while the lipids face toward each other in the inner part of the membrane. A technique used to split the two layers, with the aid of electron microscopy, positively identified the structure of the cell membrane. Figure C2.12(a) shows the two layers of the cell membrane separated and laid side by side, as seen through the electron microscope. Proteins are suspended in the phospholipid bilayer, some attaching to the outside of the cell membrane, some attaching to the inside of the cell membrane, and some running through the membrane. Some surface proteins have sugar molecules attached. The currently accepted structure of the cell membrane was suggested in 1972 and is referred to as the **fluid-mosaic model**. A mosaic is a collection of different substances held together

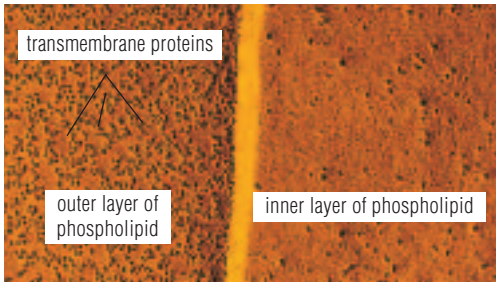
FIGURE C2.11 A Roman mosaic floor has small pieces of tile held together by a common material. Scientists suggest that the cell membrane has some aspects similar to a mosaic.

by a common material (Figure C2.11). From above, the cell membrane looks like a mosaic of tiles (the proteins) held together by a fluid, flowing grout (the lipid bilayer). The model is shown in Figure C2.12(b). Each part of the membrane has a role to play in allowing the movement of nutrients, gases, and wastes into and out of the cell. These roles will be discussed in section C2.2.

The cell membrane is a protective barrier between the environment and the cell's fragile contents. Inside the cell membrane is the cytoplasm, a gel-like substance that contains primarily water, salts, dissolved gases, dissolved nutrients, and organelles. The cytoplasm is often compared to a gelatin dessert with one important difference: the cytoplasm moves and flows inside the cell membrane.

reSEARCH

Investigate how sugar molecules attached to membrane proteins may enable cells to recognize foreign substances or to interact with each other. Begin your search at www.pearsoned.ca/school/science10



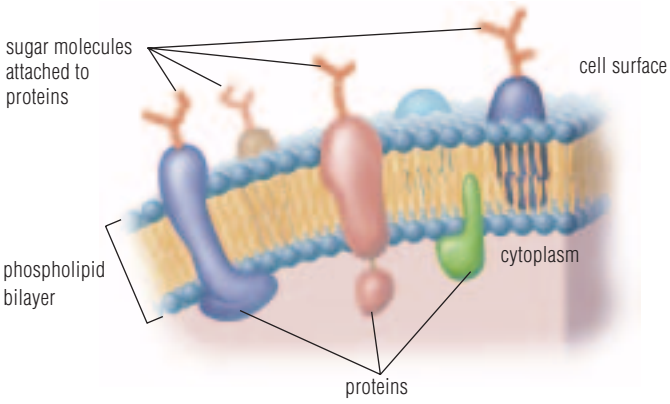


FIGURE C2.12 (a) A TEM showing that the cell membrane can be split into inner and outer layers laid side by side. Most proteins stay with the outer layer of phospholipids. (approx. ×200 000)

(b) The fluid-mosaic model of the cell membrane

C2.1 Check and Reflect

Knowledge

1. What is meant by a system?
2. Describe what makes the cell an open system.
3. Draw a diagram of a plant cell. Label the organelles and state the function of each.
4. Using your own words, describe the appearance and state the function of the following cell structures:
   a) cell membrane
   b) vacuoles
   c) mitochondria
   d) chloroplasts
5. Identify the organelle associated with the following life processes: intake of nutrients; exchange of gases; removal of wastes.
6. What are trace elements in the cell?
7. List three similarities and three differences in the chemical composition of plant and animal cells.

Applications

8. Construct a chart showing the organelles in a cell and identify a human organ that performs the same or similar function in the body as a whole.
9. Consider what happens to the human body if an organ fails. What would happen if one of the cell organelles failed? In a short paragraph, provide the reasoning for your prediction.
10. Compare the structure and function of an animal cell and a plant cell.

Extensions

11. Create a concept map to show the relationships between the organelles.
12. Create a three-dimensional model of a cell using any materials of your choice. Use your knowledge to attempt to make the organelles as correct to scale as possible.

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In 1996 researchers found that the disease cystic fibrosis creates a defective transport protein that prevents sodium ions from crossing the cell membrane in lung cells. The build-up of sodium outside the cells makes these cells susceptible to bacteria.

C2.2 The Role of the Cell Membrane in Transport

The transport of gases, nutrients, and wastes into and out of the cell is essential for the cell's survival. The cell membrane is the organelle responsible for transport. The substances that enter and leave the cell may be ions or molecules or, in some cases, micro-organisms or other cells. In a physical sense, all of these substances can be regarded as particles, and their behaviour can be examined with reference to the particle model of matter.

The Particle Model of Matter

You will recall the particle model of matter, which helps us to explain the nature of matter, from your studies in previous grades. We can use this model to help us understand the process of transport in a cell. The particle model has four main points:

1. All matter is made of particles but the particles in different substances may be different in size and composition.
2. The particles of matter are constantly moving or vibrating; particles move least in solids and most in gases. Adding or taking away energy will affect the movement of particles.
3. The particles of matter are attracted to one another or are bonded together.
4. Particles have spaces between them that are smallest in solids, except for ice, and greatest in gases. The spaces may be occupied by the particles of other substances.

As you learn about the transport of material in cells in this section, try to relate to the particle model of matter to help your understanding of the different types of transport.

Minds On... Diffusion

Try this in your class.

1. Spread out through the classroom.
2. Have one student draw a map of the location of each person or group of people on the board.
3. Have another student, standing in one corner of the room, open a sealed package of coffee or a sealed bag of microwaved popcorn.
4. Have individuals indicate when they smell the coffee or popcorn by raising their hands. Record the order of students' signals on the map.

Questions

1. Using the particle model of matter, explain what has happened and why. Be as specific as possible.
2. Refer to Figure C2.13. Use the particle model to explain what has happened in the Petri dish.
3. List the similarities and differences between the coffee or popcorn aroma in the room and the food colouring in the Petri dish.

Diffusion

Roasted coffee contains as many as 800 flavour compounds, which may vaporize, releasing aroma molecules into the air when a fresh package of coffee is opened. The process you observed with the coffee demonstrates **diffusion**, the natural movement of particles from an area of high concentration to an area of low concentration. The place where the coffee was opened had many aroma particles. Since these particles are in constant motion, some of them are able to move into the spaces between the particles of the air, spreading out until they are equally spaced throughout the room. This process may take a few seconds or continue for a longer period of time. The end result is a state of equilibrium, in which the particles are still moving but maintain an overall balanced, even distribution. Figure C2.13 shows diffusion in the liquid state. The coloured liquid will eventually spread evenly throughout. The **rate of diffusion** can be increased by adding energy and increasing molecular movement, for example, by stirring or heating, but the process of diffusion will continue even in the absence of added energy.

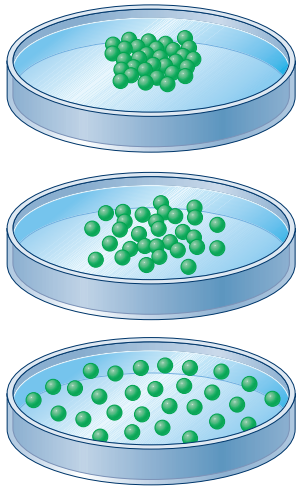

FIGURE C2.13 The movement of particles in a liquid will result in an even distribution.

Diffusion also occurs in cells. As discussed earlier, water is a major component in plant and animal cells. It is the solvent that provides the environment for all biological reactions. Diffusion of water or **solutes** can occur across a cell membrane if there is a difference between the concentrations of water or solutes on either side of the membrane, or within the cytoplasm if there is a concentration difference between areas of the cytoplasm. This difference between the concentrations is called a concentration gradient. The **concentration gradient** determines the direction in which water or solutes will move. In the cell, the cell membrane is the gatekeeper trying to maintain equilibrium of particles on either side.

Movement of material by the process of diffusion is considered to be **passive transport** because no added energy is required for it to occur. The energy inherent in the particles themselves is sufficient for the movement along the concentration gradient to occur.

The essential things for the cell are to allow needed substances to enter, to keep other substances outside, and to maintain substances at an equilibrium that is favourable to the life processes. The cell membrane is considered to be **selectively permeable** because it allows certain particles to pass through it, but not all particles. The membranes used in desalination and water treatment, discussed earlier in this unit, mimic the natural functioning of the cell membrane. Membranes that do this are called **semi-permeable** membranes. Generally, the passage of materials through the cell membrane is determined by the size of the molecules, their charge, and whether they are soluble in lipids. Particles that are too large will not get through. Only particles that are soluble in lipids or that are small enough to pass through the pores of the cell membrane will diffuse. Carbon dioxide, a waste product of cells, leaves the cell by diffusion because the concentration of the gas inside the cell is greater than its concentration outside the cell. Living cells require oxygen, a gas that is usually in higher concentration outside the cell. Oxygen diffuses across the cell membrane into the cell. In general, particles move from an area of high concentration to an area where their concentration is lower.

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The particle model states that the particles of a gas have more energy and move more rapidly than the particles of a liquid. In addition, the particles of a gas have larger spaces between them than the particles of a liquid. Therefore, diffusion will occur more quickly in a gas than in a liquid.

Activity C8

Inquiry Lab

Student Reference 2

Required Skills
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Movement across a Semi-Permeable Membrane

The Question

What happens when a model cell containing starch is placed in water containing iodine?

The Hypothesis

State a hypothesis based on what you know about semi-permeable membranes.

Materials and Equipment

zipper lock plastic bag
500-mL beaker
cornstarch solution prepared by your teacher
iodine tincture in a dropper bottle
test tube rack
4 test tubes
1 dropper
10-mL graduated cylinder or graduated pipette

Procedure

1. Add approximately 200 mL of tap water and one dropperful of iodine tincture to the 500-mL beaker.
2. Half fill a zipper lock plastic bag with tap water and seal. Observe the bag to be sure that it does not leak by tipping it upside down and checking for openings.
3. When you are sure that the bag is leak-proof, empty the water and add starch solution so that it fills half of the bag. Remove as much air as possible, seal the bag, and rinse it thoroughly with tap water. Place the bag in the beaker of water containing iodine tincture. Set aside for 20–30 minutes.
4. In the meantime, set up four clean test tubes in a test tube rack. Add 2.5 mL of water to test tubes 1 and 2, and 2.5 mL of starch solution to test tubes 3 and 4.
5. Add 5 drops of iodine tincture to test tube 2 containing water and to test tube 4 containing starch solution. See Figure C2.14.

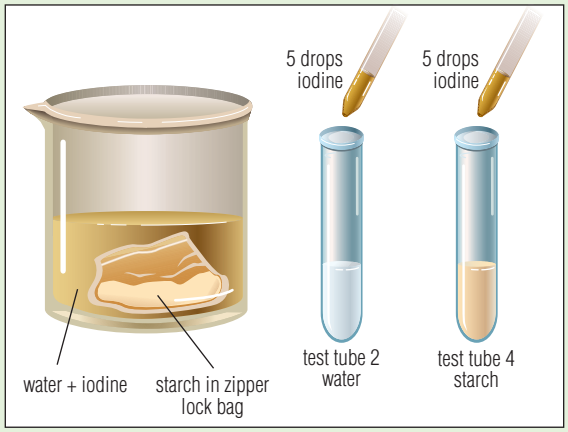

FIGURE C2.14 The experimental set-up for steps 3–5

6. Record your observations for the four test tubes.
7. Return to the 500-mL beaker and observe the starch solution in the bag.
8. Record your observations.

Analyzing and Interpreting

1. What is the result of adding iodine tincture to water (test tube 2) and to starch (test tube 4)? What can you infer from these results?
2. What is the reason for having test tubes 1 and 3 in the activity?
3. Describe the colour changes that result from placing the plastic bag containing starch into the beaker of water plus iodine. Which substance was able to pass through the plastic bag? Write a short paragraph to explain your results.
4. Consider the 'tightness' of the bag at the beginning and end of the experiment. What does this indicate about the volume of solution inside the bag at the end of the experiment? What substance is causing this change in volume? Explain your observations.

Forming Conclusions

5. Did the results of the experiment support your hypothesis? State a conclusion.

Concentration Gradients

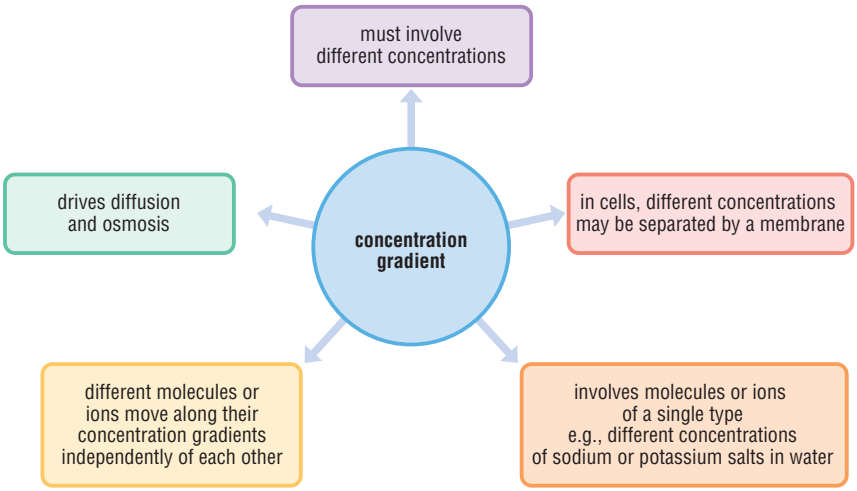

FIGURE C2.15 A graphic of key points related to concentration gradients

Figure C2.15 shows the concepts related to a concentration gradient. The operation of a concentration gradient can be demonstrated by using a plastic bag containing cornstarch solution as a model for a cell and cell membrane. The plastic has pores of a particular size that allow ions and small molecules to pass through, but prevent large particles such as starch molecules from passing. If iodine ions are in higher concentration outside the bag than inside, they will move along their concentration gradient into the bag. The passage of the iodine ion from the solution outside the bag into the starch solution is indicated by a change in colour of the cornstarch solution. Water also can move down its concentration gradient into the bag, as is indicated by the change in volume of solution inside the bag. The starch molecules cannot move along their concentration gradient because they are prevented from leaving the bag by the semi-permeable plastic membrane.

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The ancient Egyptians, Greeks, and Aztecs used honey as a medicine to promote the healing of wounds. Until recently it was believed that honey's antibacterial properties were due to its high sugar content. However, natural honey kills bacteria three times more effectively than an artificial sugar solution of the same concentration; this new evidence suggests other active ingredients are present in this traditional medicine.

Osmosis

Because the cell is an open system, it always responds to the conditions of its environment. If there is a concentration gradient across the cell membrane but the solute molecules are not able to pass through, there will be a net movement of water molecules through the cell membrane. Water molecules move along their concentration gradient from an area of high water concentration to an area of lower water concentration (Figure C2.16). The diffusion of water across the cell membrane is called **osmosis**; it is another example of passive transport.

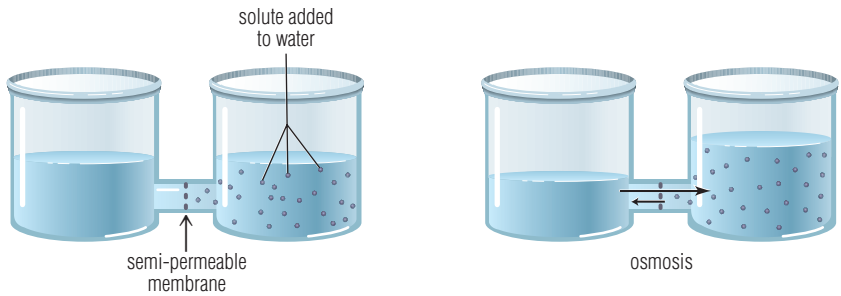
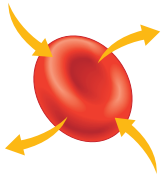
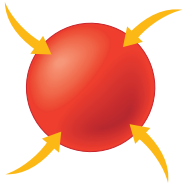


FIGURE C2.16 Osmosis is the movement of water through a membrane in response to its concentration gradient. The membrane is not permeable to the solute.

(a) Hypertonic
The concentration of solutes outside is higher than it is inside the cell.



(b) Isotonic
The concentration of solutes outside the cell is equal to that inside the cell.



(c) Hypotonic
The concentration of solutes outside is lower than it is inside the cell.

FIGURE C2.17 The movement of water molecules, when a cell is placed in solutions that are hypertonic, isotonic, and hypotonic to the cell contents, results in changes in cell shape.

To predict the direction in which a net movement of water will occur, we need to compare the solute concentration. A solution that has a higher concentration of solutes than that in a cell is said to be **hypertonic** ("hyper" means over) to the cell. This solution has more solute particles and, therefore, relatively less water than the cell contents. If the cell is put into this solution, water will leave the cell. A solution that has a lower concentration of solutes than that in a cell is said to be **hypotonic** ("hypo" means under) to the cell. This solution has fewer solute particles and relatively more water than the cell contents. If the cell is put into this solution, water will enter the cell.

A solution that has the same concentration of solutes as that in the cell is said to be **isotonic** ("iso" means equal) to the cell. If a cell is put into an isotonic solution, there is no net movement of water molecules. There will still be movement of individual water molecules into and out of the cell, but the overall concentration on both sides of the membrane will remain constant. The movement of water across the cell membrane is so easy that, even in an isotonic solution, water constantly moves back and forth. Figure C2.17 shows the response of an animal cell to three different conditions in the environment. In a plant cell, the maximum volume is determined by the rigid cell wall. The tendency of water to move into the plant cell creates a pressure, called turgor pressure, that acts to support the plant's structure. Figures C3.13 on page 309 and C3.21 on page 320 show some of the effects of turgor pressure in plants.

Facilitated Diffusion

Only substances that are soluble in lipids can pass through the lipid bilayer by diffusion. Substances that are soluble in water but not in lipids need some way of crossing the cell membrane. The protein part of the membrane is involved. **Channel proteins** create pores or channels through which small water-soluble particles are able to move. These small molecules move in response to the concentration gradient. **Carrier proteins** have the ability to attach to larger molecules that are not able to diffuse across the membrane. The carrier protein changes shape and physically moves the molecule across the membrane and into the cell. Once the molecule has been transported, the protein returns to its original shape. This process is called **facilitated diffusion**, because the movement is in response to the concentration gradient but needs the presence of the protein facilitator. These two forms of protein-mediated transport are examples of passive transport, because no added energy is needed for the process to occur.

Active Transport

At times, transport by way of a protein carrier in the cell membrane requires energy input because, in some cases, it is necessary for the cell to move particles against the concentration gradient, from an area of low concentration to an area of high concentration. This method is called **active transport**. It may be necessary for the concentration of materials such as nutrients inside the cell or for the expulsion of materials even though they are at a higher concentration on the outside of the cell. The carrier proteins work almost as a pump to

move molecules or ions across the membrane. This is like swimming upstream. It is very difficult and requires energy.

Unlike the passive processes of diffusion, osmosis, and facilitated diffusion, which do not require energy, active transport requires energy from the cell to move materials against the concentration gradient. The energy needed is produced in the mitochondria through the process of cellular respiration and comes from a substance called **adenosine triphosphate** or **ATP**. A series of chemical reactions occurs, first in the cytoplasm and then in the mitochondria, to break down glucose and produce the ATP. A comparison of diffusion, facilitated diffusion, and active transport is shown in Figure C2.18.

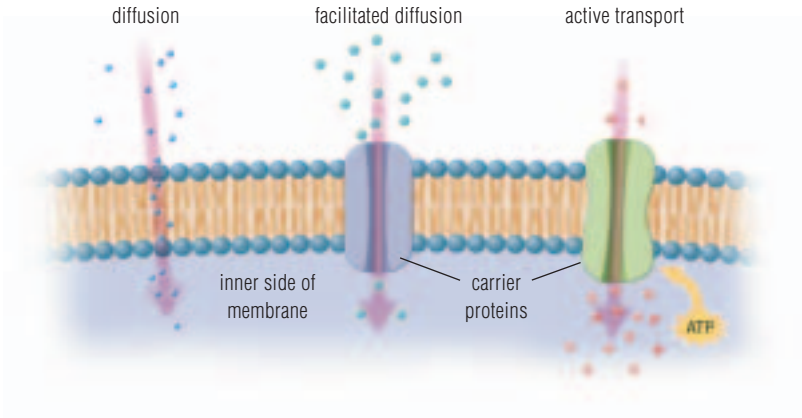


FIGURE C2.18 A comparison of the processes of diffusion, facilitated diffusion, and active transport

Skill Practice — Linking Conclusions to Hypotheses

In any science inquiry activity, you will follow a series of steps from an initial question to the formation of a conclusion. This Skill Practice gives you the opportunity to review the skills needed to perform these steps.

A student was asked an initial question. Why do vegetables like carrots and celery become crispy when placed in a container of water?

1. State a hypothesis to answer this question.

The student designed an experiment to investigate the question above. The experimental design used potato slices of the same initial mass placed in salt solutions of various concentrations. After a standard time period, the mass of each slice was obtained and the percent change in mass was calculated. Figure C2.19 shows the graph of the data obtained in the experiment.

2. a) If the data were analyzed, what would a zero percent change in mass indicate? What could you infer if you obtained this result?

b) What would a positive percent change in mass indicate? What could you infer if you obtained this result?

c) What would a negative percent change in mass indicate? What could you infer if you obtained this result?

3. Interpret the graph of Percent Change in Mass of Potato Slices vs. Concentration of Salt Solution shown in Figure C2.19, and draw inferences from the data.

4. State a conclusion about the problem of vegetable crispiness and whether your hypothesis was accepted or rejected.

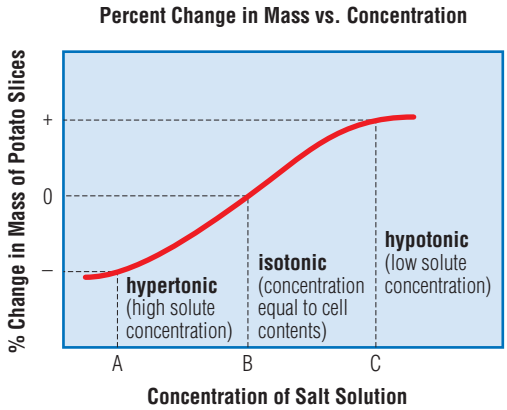


FIGURE C2.19 Graph of change in mass versus concentration

Activity C9

QuickLab

The Incredible Egg

A hen's egg is a very large cell. This cell has the nucleus attached to a food source, the yolk. The egg white or albumen surrounds the yolk and contributes materials to the growing chick. A very thin membrane surrounds the yolk and albumen. You can see the colourless membrane when you carefully crack an egg and peel away the shell. The membrane allows oxygen to get to the chick and moves carbon dioxide out of the egg. These gases are able to get to the membrane through more than 7000 tiny pores in the eggshell. When eggs are laid, they are covered with a thin mucous layer to prevent water loss. Eggs sold in stores have a mineral oil coating for the same reason.

Purpose

To observe the movement of materials into and out of a hen's egg

Materials and Equipment

one egg—shell dissolved

distilled water

10% salt solution

two 250-mL beakers

top-loading or pan balance (measuring in grams (g))

plastic spoon

paper towel

CAUTION: Wear gloves when handling the eggs. Wash your hands at the beginning and end of this activity.

Procedure

1. Set up a data table similar to the table below in your notebook. Remember to give your table a title.

Step	Starting Mass of Egg (g)	Final Mass of Egg (g)	Observations
Submerge in 10% salt solution			
Submerge in distilled water			

2. Obtain a hen's egg prepared by your teacher. The eggs are in distilled water but were previously placed in a weak acetic acid solution to dissolve the shell. Carefully remove the egg with the spoon and pat dry with a paper towel. Record the mass of the egg and your observations of the egg at the start of the activity in your table.
3. Submerge the egg in a beaker containing a 10% salt solution. Allow the egg to sit for 8 minutes.
4. Carefully remove the egg with the spoon and rinse it under running water. Pat dry with a paper towel and record the final mass of the egg after treatment with the salt solution. Record any changes that you observe in the egg due to submerging in the salt solution.
5. Submerge the egg in a beaker of distilled water for 15 minutes. The starting mass of the egg for this section will be the same as the final mass for the previous section. Record this mass in your table.
6. Carefully remove the egg with the spoon and rinse it under running water. Pat dry with a paper towel and record the mass of the egg and any changes that you observe in the egg due to submerging it in distilled water.
7. Dispose of the egg as indicated by your teacher.

Questions

1. In a short paragraph explain what happened to the egg when it was placed in the salt solution. Include the appearance and mass of the egg following this step.
2. Explain what happened to the egg after it was placed in the distilled water for 15 minutes.
3. Draw a diagram to show the movement of substances across the membrane of the egg in the two experimental treatments.
4. Use the particle theory and your understanding of concentration gradients to explain the indirect evidence of osmosis provided by this experiment.
5. Explain why water was able to move across the membrane but salt was not.

You can use a hen's egg to demonstrate osmosis, the movement of water in response to its concentration gradient. When an egg is immersed in an acidic solution the shell will dissolve, leaving the membrane intact. If the shell-less egg is placed in a 10% salt solution, water will leave the egg by osmosis and the mass of the egg will decrease. If the egg is transferred to distilled water, the concentration gradient will be reversed. Water will enter the cell through the membrane and the mass of the egg will increase.

Endocytosis and Exocytosis

In some cases, molecules that need to be taken in by the cell, or secreted from it, are too large to pass across the cell membrane, even with the help of protein carriers. In these cases, the cell has another option—to use vesicles, sacs that surround the large particle and contain it. These sacs are similar to vacuoles in structure, but are usually small and temporary. When an amoeba, for example, comes upon a food particle, it engulfs the particle by folding pseudopods around it. A vesicle forms around the particle and the cell membrane pinches off around it so that the vesicle is inside the cell. This process is called **endocytosis** (Figure C2.20).

Similar steps, but in the reverse order, occur when the cell must rid itself of large waste particles, or when a secretory cell releases product molecules. A vesicle surrounds the particle, then moves to the plasma membrane and fuses with it. The vesicle then ruptures, releasing its contents into the surroundings, as shown in Figure C2.21. This process of secretion is called **exocytosis**. Both exocytosis and endocytosis require energy from ATP for the rearrangement of the cell membrane.

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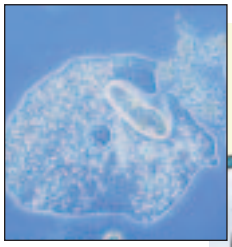
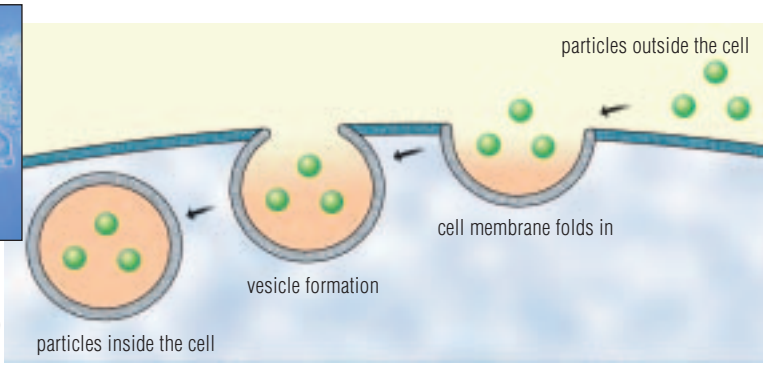
You may be interested in researching some aspects of endocytosis:
Phagocytosis: a form of endocytosis that occurs in specialized cells and involves the ingestion of large particles (e.g., bacteria) within a vacuole. The bacterium is destroyed by enzymes that enter the vacuole.
Pinocytosis: a form of endocytosis that occurs in almost all cells. The cells engulf minute molecules and ions in the environment.
Receptor-mediated endocytosis: receptor proteins bring specific molecules into the cell by endocytosis.
Begin your search at
www.pearsoned.ca/school/science10

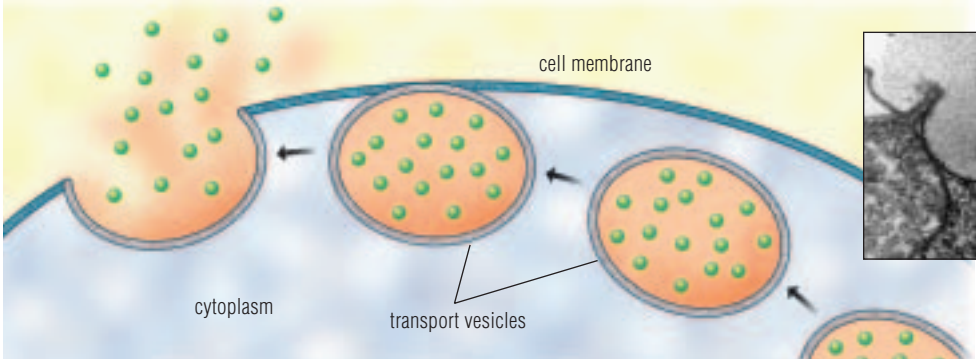


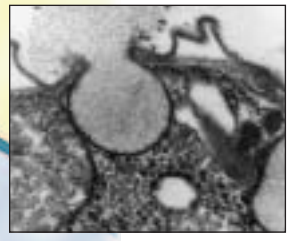
(a) *Amoeba* feeding by endocytosis: phase contrast (approx. ×90)



(b) Particles are brought into the cell by the folding-in of the cell membrane to form a vacuole or vesicle.

FIGURE C2.20 The process of endocytosis





TEM ×36 000

FIGURE C2.21 In the process of exocytosis, a vesicle fuses with the cell membrane and then ruptures to release its contents outside the cell.

Activity C10

Problem-Solving Investigation

Student Reference 3

Required Skills
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Building Exhibit Models

A model is a working representation of a concept, object, or process. The use of models helps in visualization of abstract concepts. An example is the use of a globe as a model of Earth.

Recognize a Need

The Science Alberta Foundation is developing a travelling exhibit aimed at describing how knowledge of cellular functions is used in industry and medicine. Your class has been asked to design, build, and test models to demonstrate diffusion, osmosis, facilitated diffusion, endocytosis, and exocytosis for the display.

The Problem

Divide into groups with each group taking one of the processes to be demonstrated in the exhibition. Collaboration and teamwork will be essential in designing, constructing, and testing your model.

Criteria for Success

- Inform and educate the general public about ways in which knowledge of cellular functions is used in industry and medicine.
- Provide an accurate representation of one of the transport mechanisms used by the cell in which the process is clearly demonstrated, including the role of the cell membrane in this process.
- Provide a poster or explanation of your working model to assist people who stop at the exhibit.
- Appeal to a large audience of people of various ages.

Build a Model

1. Review everything you know about the process you are modelling, and jot down the most important characteristics that you will need to demonstrate in the model.
2. Discuss the materials available to you and what you would like to use.
3. Decide on the responsibility of each member of the group and determine how you will apportion your time to meet the deadline set for fabrication of the display (your teacher will provide this information).
4. Choose your own materials.
5. Design your model.
6. Obtain approval from your teacher.
7. Build your model.

CAUTION: Consider and follow safety precautions while building your model. Remember that others will be using the model also, so you have a responsibility for their safety as well.

Test and Evaluate

8. Test your model at least three times to ensure that it will work over and over again in the exhibition. Evaluate each test and re-design or re-work as required. You may want to get input from other groups as you perfect the model.
9. Review what you know about the biological process to ensure that your model is accurate.

Communicate

1. Set up your model and the accompanying poster or explanation. Conduct a "staff testing" by having each group work through each of the models and provide constructive feedback to the group who designed the model. Make the necessary changes.
2. Conduct a "focus group testing" with students from other classes, teachers, or parents. Your display is now ready to go on tour!

C2.2 Check and Reflect

Knowledge

1. Explain the four points of the particle model of matter.
2. Explain how the processes of diffusion, facilitated diffusion, and active transport occur and why each one is important to cells.
3. Using your own words, explain what is meant by the terms "concentration gradient" and "equilibrium."
4. Explain how you would ensure that the celery you bought three days ago will be crisp and fresh for your dinner tonight.
5. What are the differences between passive and active transport?
6. Draw two diagrams showing the processes of endocytosis and exocytosis. Indicate the similarities and differences.

Applications

7. Imagine three identical animal cells, each placed in one of three beakers labelled A, B, or C. Beaker A contains a solution that is hypertonic to the cell contents; Beaker B contains a solution that is hypotonic to the cell contents; Beaker C contains a solution that is isotonic to the cell contents. Predict what will happen to the cells in each beaker. Give reasons for your prediction.
8. The principles of osmosis are used in food preservation. Certain foods are stored in strong salt solutions (brine) or in syrups to prevent infection by microbes.
   a) Explain how the principles of osmosis apply to this situation.
   b) What effect will these solutions have on the micro-organisms?
9. Use the particle model to explain how the size of particles would affect the rate of diffusion.

Extensions

10. Give some examples of how the cell membrane helps the cell to maintain equilibrium through exchange of materials with its environment.
11. Research an example of active transport in a cell. Present your findings in a poster or PowerPoint presentation.
12. Using a plastic grocery bag to represent the cell membrane, and wrapped candies as a food source, demonstrate the process of endocytosis. You may use your hands inside the bag as the movement of the cytoplasm, and scissors and tape to accomplish the pinching off of the membrane. Do not turn the bag inside out or expose the cytoplasm. You must be able to demonstrate the vesicle formation. Draw a diagram of your model to explain what you did.

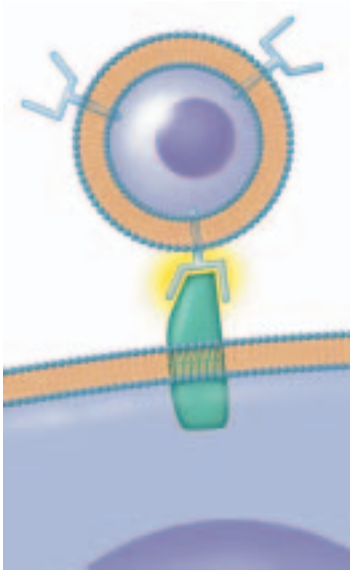


FIGURE C2.22 Recognition proteins on the cell surface allow cell communication.

C 2.3 Applications of Cellular Transport in Industry and Medicine

Knowledge about the make-up and functions of the cell membrane and about methods of transporting substances into cells has advanced research in both industry and medicine. Efficient natural systems are often the model for manufactured systems, and the cell membrane is an excellent example of a selective gatekeeper. Knowledge about the cell membrane has prompted industrial use of synthetics to mimic natural functions. This area of research and development is known as **membrane technologies**.

The molecules associated with the cell membrane on the surface of the cell are important for many cell activities. Some proteins, called **recognition proteins**, are embedded in the cell membrane, but stick out into the cell's surroundings. They allow cells to recognize one another; for example, when egg and sperm cells link together, or when cells of the human immune system recognize and destroy invading bacteria and viruses or destroy newly arisen cancer cells. Figure C2.22 shows a model of the link between recognition proteins on the surface of different cells

Other proteins called **receptor proteins** may bind specifically with certain molecules to bring them into the cell by endocytosis. Some of these proteins have sugar groups attached to them that make the binding specific and allow the cell to identify a particular bacteria or virus. In a reverse way that has a negative effect on humans, some viruses like human immunodeficiency virus (HIV), hepatitis, and influenza, use the binding reaction to target human cells (Figure C2.23). In other cases, the binding reaction on the surface of the cell acts like a molecular switch and triggers many different activities in the cell.

Pharmaceutical research draws on this understanding of cell membrane proteins to develop and test new drug therapies, making use of the cell's ability (either that of the disease-causing organism or of the host) to recognize molecules. This is one of the reasons why studies of the three-dimensional shape of molecules are important to health research as well as being of interest in themselves.

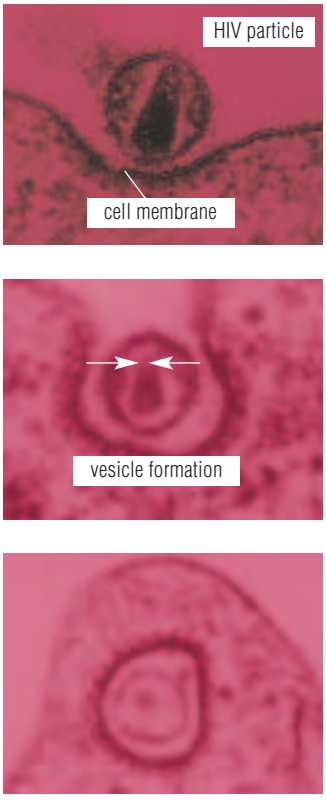


FIGURE C2.23 Viruses like HIV can enter cells by endocytosis. Transmission electron micrographs (approx. ×450 000)

Membrane Proteins and Disease

Researchers have been working long and hard to find treatments and cures for constantly changing viruses such as HIV. New discoveries focus on recognition or receptor proteins in human cell membranes that appear to be the attachment point for the virus. In understanding these proteins, scientists suspect that they may be able to produce a lock-and-key scenario that would prevent the virus getting into the cell. The process would work to block or close off the receptor protein so that the "key" produced by the virus would not work—the virus would essentially be locked out (Figure C2.24). Imagine covering the keyhole of a padlock with cement so that even if you had the right key for the lock, you would be unable to use

it. Being able to turn the virus away in this manner would mean that it would not be necessary to deluge the body with drugs that could affect healthy cells as well as infected ones. The disease could be stopped before it takes hold.

Cancer research has also targeted the study of recognition proteins. Common treatments for cancer are not able to single out only the defective cells; they affect healthy cells as well. If it were possible to identify the unique proteins of cancer cells, it might be possible to develop drugs specific to these proteins, and therefore specific only to cancer cells. Further, if certain recognition proteins specific to cancer cells could be identified, they could be used to stimulate the immune system to detect and destroy the cancer. The ability to be specific and target only cells of the cancer would mean less overall discomfort to the patient.

Synthetic Membrane Technology

While protein research continues, drug therapies also use a structure manufactured to act like the cell membrane. **Liposomes**, as shown in Figure C2.25, are fluid-filled sacs surrounded by a phospholipid bilayer identical to the cell membrane in human cells. Liposomes were first produced in the early 1960s and have since become important agents in the delivery of drugs to infected body tissue. They can be produced for almost any need by manipulating the composition of the membrane. Liposomes are microscopic, about 1/1000th the diameter of a human hair. Water trapped on the inside can hold water-soluble medications while the membrane layer is able to hold fat-soluble medications. The tiny sacs can be introduced into the bloodstream and circulate throughout the body. Because the membrane is identical to that of human cells, the liposomes can attach to infected cells and deliver the medication.

HIV and cancer therapies make use of liposomes to deliver medication. The advantage of using liposomes is that the spheres may circulate in the bloodstream for longer than the medication on its own, allowing for longer, sustained treatment. Sometimes, liposomes concentrate themselves at the site of a tumour or infection, and in this way deliver the drug directly to the targeted cells without affecting normal cells.

The use of liposomes in gene therapy to inject DNA into tumour cells is another application of liposomes that is actively being researched. The DNA is contained inside the liposome. A molecule on the liposome surface fits on to certain cancer cells to recognize and target the correct cells. In this way, the DNA can be introduced into the tumour cells, and begin the production of toxins to kill the cell. However, more research is required to ensure that healthy cells are not also susceptible to the gene- or drug-carrying liposomes.

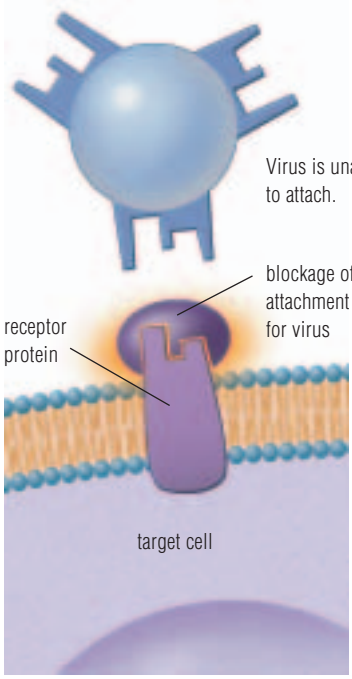


FIGURE C2.24 One possible way of fighting attachment of a virus

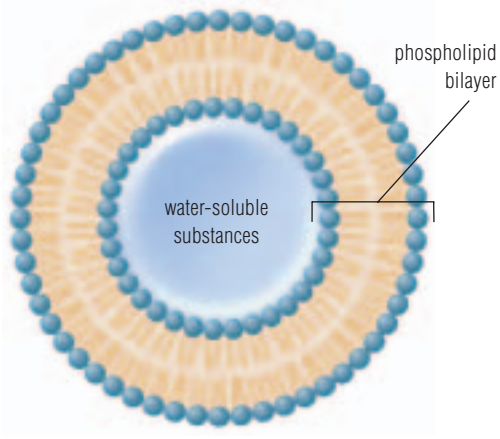


FIGURE C2.25 The phospholipid bilayer forming the liposome allows water-soluble substances to be carried inside the liposome.

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Scientists are working on the production of synthetic vaccines using molecules that resemble parts of the cell membrane of disease-causing cells. The aim is protection against disease without any risk of the person becoming ill.

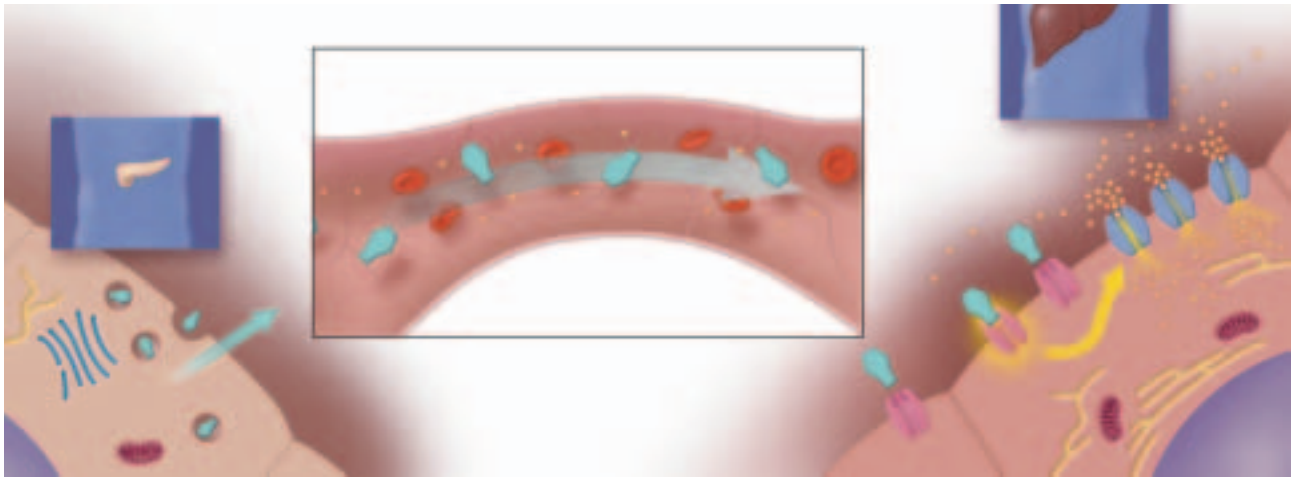

FIGURE C2.26 A model of the mechanism of insulin action

Transport of Protein Hormones

Insulin is a small protein produced in the pancreas. It is a hormone, meaning that it is secreted into the bloodstream and binds with membrane receptors at a distance from the point of secretion. The complex formed between the hormone and the target cell triggers the target cell to undergo particular processes.

Specialized cells in the pancreas have channels that detect glucose (so-called blood sugar) in the bloodstream. This initiates the excretion of insulin into the blood. Insulin binds to receptor proteins of tissues including liver, muscle, and fat. This binding stimulates the rate of movement of glucose into the cells through facilitated diffusion using a carrier protein. Glucose is then used either directly to produce energy, or stored as a future source of energy as glycogen in the liver, fat in the fat tissue, and protein in the muscle. Figure C2.26 shows a model of the mechanism of insulin action.

info BIT

People with Type I diabetes are not able to produce insulin and must take injections of insulin to regulate their blood sugar levels. The "diabetes pill" is available to some Type II diabetes patients whose pancreas still produces insulin. The pill does not contain insulin, but may stimulate the pancreas to produce more insulin or make the body more sensitive to the insulin that is being produced. The safety of some types of diabetes pills is being monitored.

Peritoneal Dialysis

Before the process of dialysis was available, people who experienced total kidney failure died. Today, the availability of dialysis and kidney transplants means that many patients can continue to live full lives. Two types of dialysis are possible: peritoneal dialysis and hemodialysis. Both are based on the principles of diffusion and osmosis and the operation of concentration gradients. The purpose of dialysis is to rid the blood of toxins, wastes, and excess fluid produced by the cells of the body. Normally, healthy kidneys would perform this task, sending wastes to be eliminated in the urine.

In humans, cells form a membrane called the **peritoneum**, which lines the abdominal cavity. During dialysis, waste products from the blood pass through these cells into a fluid, the dialysate fluid. This is termed **peritoneal dialysis**. A soft plastic tube (catheter) is surgically inserted into the abdominal cavity. The sterile dialysate fluid is pumped into the cavity. The dialysate has a composition similar to human body fluids and consists of a

FIGURE C2.27 A person can continue most activities while performing peritoneal dialysis.

mixture of water, glucose, and certain substances the body needs. Dialysate usually contains sodium, magnesium, chloride, potassium, and calcium salts. The dialysate has no toxins or wastes present, so the concentration of these materials in the blood is much higher than it is in the fluid on the other side of the peritoneal membrane. The movement of toxins and wastes is down the concentration gradient. The wastes diffuse across the membrane and into the dialysate. As the cleansing fluid becomes saturated or full of wastes, it is removed from the body, disposed of, and replaced with fresh dialysate until the entire exchange process is complete.

The patient is able to perform peritoneal dialysis at home while carrying on most activities. **Hemodialysis**, on the other hand, is a more complicated procedure and must be performed in a health facility. The blood must be removed from the body, cleansed using a dialysate fluid in a special machine, and returned to the body. The patient is not able to move around during hemodialysis.

Minds On... Simulating Peritoneal Dialysis

In groups, discuss what you know about diffusion, osmosis, and semi-permeable membranes. Consider how knowledge of these concepts was used to develop the technology of dialysis that is now used to save so many lives.

Design a representation of the movement of materials across the peritoneum. You may choose a diagram, poster, model, role play, or another format of your choice to explain the workings of dialysis.

Reverse Osmosis

Antarctica is a frigid and remote continent, not easily accessible for most of the year. Researchers and other workers living at the research facilities there must be in good physical, emotional, and mental health. As well, the technologies used must be reliable and efficient. The McMurdo Research Station is charged with meeting the needs of the people living there and addressing the question of how to provide potable water.

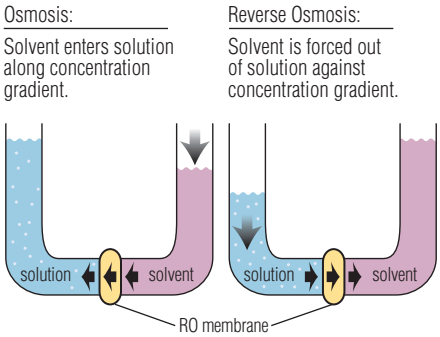

FIGURE C2.28 Reverse osmosis pumps water against its concentration gradient to remove charged particles.

Desalination is the process of removing salt from sea water in order to make it suitable for drinking. Sea water in Antarctica is very cold, so it is first warmed slightly and then pumped through a 25-µm filter to eliminate coarse materials. The filter contains layers of anthracite coal, sand, garnet, and limestone. The water is pumped through progressively smaller filters that allow only smaller and smaller particles to pass through. The process is referred to as **reverse osmosis (RO)** because the water moves from a low water concentration (high concentration of solute) to a high water concentration (low concentration of solute) and therefore requires the force of pressure of a pump (Figure C2.28).

RO makes use of semi-permeable membranes that allow the water to be forced through but filter out other molecules or micro-organisms of progressively smaller and smaller size. As this process proceeds, the rejected materials continue to increase in solute concentration, requiring more force to push the water through. Reverse osmosis is affected by charged particles, like salts, so that the larger the molecule and the greater the charge on it, the less likely it will be to move through the membrane. "Backwash" from the filtration process helps to keep the filter clean. Following the RO process, the pH levels of the water are adjusted and chlorine is added to kill any bacteria still present. RO is an efficient, but expensive, method of desalinating and purifying water in Antarctica and other places of the world where fresh water is in extremely short supply. RO systems are now available for home water-purification.

*re*SEARCH

Find out how membrane technology is used in the modern dairy industry. Begin your search at www.pearsoned.ca/school/science10

C2.3 Check and Reflect

Knowledge

1. *The transport of wastes out of the blood during dialysis depends on the composition of the dialysis solution.* Explain this statement. You should include the particle model of diffusion and the role of the cell membrane in your answer.
2. Draw and label a diagram of a liposome. How are liposomes used in the treatment of HIV and cancer patients?
3. Describe the role of membrane technologies in the following:
   a) water purification
   b) peritoneal dialysis
   c) gene therapy for cancer
4. List three differences between peritoneal dialysis and hemodialysis.
5. Explain the term "reverse osmosis" as compared with "osmosis."
6. Explain the importance of membrane binding to the action of insulin.

Applications

7. What methods of water treatment are used in your area to provide potable water?
8. Describe some of the limitations of membrane technologies in the treatment of HIV, diabetes, cancer, and kidney disease.

Extensions

9. Write an article for an imaginary science journal, highlighting the importance of the cell membrane in the development of one commercial process.
10. Create a Web site to explain what you know about cell membranes, diffusion, osmosis, and applications in industry and medicine.

C 2.4 Is Bigger Better?

Whether we consider a one-celled amoeba, a giant sequoia tree, or a lumbering elephant, cells are all microscopic in size. Why are cells so small? Wouldn't it make more sense for cells to grow to a larger size? That way, the human body, for instance, could be made up of a few hundred large cells instead of trillions of tiny ones. And yet, the cell is considered to be an efficient system. Is there an explanation for the small size of cells?

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In hot weather dogs tend to lie stretched out but in the cold they curl into a tight ball. A sphere has a small surface area, so your curled-up dog is minimizing the transfer of heat from his body to the surroundings.

The Ratio of Surface Area to Volume

As an efficient, open system, the cell must be able to carry out all of the life processes. The transport of materials into and out of the cell is critical because these materials will determine how the other processes function. The cell membrane is the barrier to free exchange between the outside environment and the cytoplasm. Whatever changes happen to the cell, the ability to transport materials must be kept at a maximum.

If a cell becomes larger and its volume increases, more molecules will need to be transported across the cell surface to take part in the cell's functions. Also, the distance any molecule has to travel from the cell surface will increase. If the cell is to maintain its ability to transport substances, there must be a greater surface area to match the increased need for molecule transport. One way to see how the surface area changes in relation to volume as the cell changes in size is to calculate the surface area to volume ratio for different cell sizes.

Example Problem C2.1

Determine the surface area to volume ratio for cubes that have the following side lengths:
a) 1.0 cm b) 2.5 cm c) 4.0 cm

A cube has 6 square faces, each having area s^2, where s is the side length.
Surface area of the cube $A = 6s^2$
Volume of the cube $v = s^3$
Surface area to volume ratio of the cube $\frac{A}{v} = \frac{6s^2}{s^3} = \frac{6}{s}$

a) $s = 1.0$ cm, $\frac{A}{v} = \frac{6}{1.0} = 6.0$

b) $s = 2.5$ cm, $\frac{A}{v} = \frac{6}{2.5} = 2.4$

c) $s = 4.0$ cm, $\frac{A}{v} = \frac{6}{4.0} = 1.5$

The surface area to volume ratios for cubes a), b), and c) are 6.0, 2.4, and 1.5, respectively.

Example Problem C2.1 shows that as a cell increases in size, its surface area to volume ratio decreases. For efficient transport at a cell's surface, the cell must have a large surface area in relation to its volume. The greater the surface area to volume ratio, the more efficient **cell transport** will be.

Practice Problems

1. Determine the surface area to volume ratio for cubes that have the following side lengths:
   a) 3.5 cm b) 5.5 cm
2. What is the formula for the surface area to volume ratio of a rectangular prism? Determine the surface area to volume ratio of a rectangular prism that has:
   length $l = 2.5$ cm;
   width $w = 2.0$ cm; and
   height $h = 1.0$ cm
3. What is the formula for the surface area to volume ratio of a sphere? Determine the surface area to volume ratio for spheres that have the following diameters:
   a) 4.3 cm b) 8.6 cm

Activity C11

Inquiry Lab

Student Reference 6

Is Bigger Better?

Required Skills

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

If you cut a cube of gelatin into pieces, the total volume occupied by all the pieces remains the same as the volume of the initial cube. However, the surface area changes and this means that the surface area to volume ratio also changes. Phenolphthalein is an indicator chemical that is pink in a basic solution but becomes colourless when it comes in contact with an acid. Phenolphthalein was added to a basic solution to make the gelatin cubes that you will be using in this experiment. You will bring dilute hydrochloric acid (0.1 mol/L $HCl_{(aq)}$) in contact with the gelatin cubes and measure diffusion by the change in colour of the gelatin. Accuracy of measurement and calculation is very important in this activity. Be as careful as possible.

The Question

How is the rate of diffusion affected by the surface area to volume ratio of a cell?

The Hypothesis

State a hypothesis indicating how you think diffusion will be affected by differences in the surface area to volume ratio of cells.

CAUTION: Acids and bases are corrosive. Handle the base-containing gel carefully. If any acid spills, wash immediately with cold water.

Materials and Equipment

3 cubes of gelatin containing phenolphthalein (each approximately 4 cm × 4 cm × 4 cm)

dilute hydrochloric acid solution (0.1 mol/L $HCl_{(aq)}$)

metric ruler

plastic knife

plastic spoon or tongs

3 250-mL beakers

graphing calculator or spreadsheet program

clock, watch, or timer

Procedure

1. Prepare a data table similar to the table below. Remember to give your table a title.
2. Take three identically sized pieces of gelatin.
3. Measure the length of the sides of one cube and record the cube side *s* in the table.
4. Calculate the surface area, volume, and surface area to volume ratio for the cube. Enter your results in the data table. If you are using a graphing calculator or spreadsheet, enter the data there.

Cube Size	Cube Side *s* (cm)	Surface Area of One Cube (cm^2)	Total Number of Cubes	Total Surface Area *A* (cm^2)	Total Volume *v* (cm^3)	Surface Area to Volume Ratio $\frac{A}{v}$
large	4					
medium	2					
small	1					

5. Take a second cube of gelatin. Cut it in half along its length, then in half again across the width, and in half again through the height.
6. Measure and record the length of the sides of one of the eight medium-sized pieces.
7. Calculate the surface area of each cube and the total surface area of all the medium-sized cubes. Enter your data in your table and graphing calculator or spreadsheet.
8. Has the total volume changed? Enter the total volume in your table.
9. Take the third cube of gelatin. Cut it into eight pieces as you did with the second cube and then cut each of the eight pieces again into eight equal pieces, resulting in 64 equal cubes.
10. Measure the cube side of one small cube. Calculate its surface area and the total surface area of all the small cubes. Enter your data in your table and graphing calculator or spreadsheet.
11. Has the total volume changed? Enter the total volume in your table.
12. Place all three sets of gelatin pieces into separate beakers and add just enough 0.1 mol/L $HCl_{(aq)}$ to cover the cubes.
13. Observe the beakers and record the time taken for the cubes to change colour completely from pink to colourless.

Analyzing and Interpreting

1. Explain how the surface area to volume ratio changes in each of the sets of cubes when the length of the side of each individual cube is decreased.
2. The colour change indicates the diffusion of the acid into the cube. The rate of diffusion $r = \frac{\text{total volume (cm}^3\text{)}}{\text{time (min)}}$. Calculate the rate of diffusion (cm^3/min) for the three sets of cubes.
3. Summarize the effect on the rate of diffusion of decreasing the size of individual cubes while increasing the number of cubes.
4. Graph your data using the surface area to volume ratio as the manipulated variable and the rate of diffusion as the responding variable.
5. State a relationship between the surface area to volume ratio and the rate of diffusion.

Forming Conclusions

6. Use your data and analysis to suggest conclusions from this investigation. Do these conclusions support your hypothesis?

Applying and Connecting

7. Consider the amount of time it takes to suck on a hard piece of candy until it completely dissolves. Predict how the time would be affected if you took an identical piece of the same candy (same shape and size), but chewed as well as sucked. Give reasons for your hypothesis. Try the experiment to see if your hypothesis is supported.

Extending

8. Is bigger better? Based on your observations, calculations, and conclusions, suggest a reason why cells are so small.

The Size and Shape of Organisms

For the survival of each cell, whether as a single-celled organism or as one cell in a mass of cells, the amount of surface exposed to the environment is crucial. The surface area determines the opportunities for transport of materials. If very little surface is available, the opportunities for intake of needed materials and expulsion of wastes are severely limited. What happens to the cell if it is unable to take in enough nutrients or is unable to remove poisons quickly?

Passive transport is one of the ways in which water, gases, and some dissolved nutrients are able to pass into and out of the cell. These materials must get quickly to all parts of the cell. The investigation of the gelatin cubes in Activity C11 showed that as the surface area to volume ratio increased, the rate of diffusion also increased. The set of cubes with the greatest surface area to volume ratio was the set with the smallest cubes. That means that the smallest cube is the one in which diffusion can be most quickly accomplished. As well, the distances materials have to travel from the surface to the other parts inside a small cube are relatively short. So, in the case of cells, bigger is not necessarily better. However, cells in multicellular organisms perform specialized functions, and their shape and size are determined by these functions.

info **BIT**

The cells of multicellular organisms are specialized to perform certain functions in the body. The different cells of the body may look very dissimilar. For example, human red blood cells are round biconcave discs while the nerve cells are long and slender. The biconcave shape provides the greatest surface area possible for a cell of the volume of the red blood cell.

Maximizing Potential

To maximize efficiency and promote survival, each individual cell needs to have the greatest possible surface area in relation to volume. In this way, there are lots of opportunities for transport of substances to occur, and the distance any molecule must travel within the cell is not too great. Multicellular organisms have evolved and adapted to balance the increased size of the organism against the need for an appropriate surface area to volume ratio. Compare a large plant and a small one, as shown in Figure C2.29. The large plant has more mass and volume. It is a challenge to maintain an optimum surface area to volume ratio in order to meet all the needs of the cells. The plant may have large, flat leaves to create as much surface area as possible for exchange and transport of materials. The smaller plant has less mass and volume. It has less problem to transport materials quickly to all the cells.

Multicellular organisms have developed other internal transport systems to reduce dependence on diffusion and to help in the transport of materials. For example, the circulatory, digestive, and respiratory systems of animals are all involved in the transport of essential materials to all the cells of the body. Transport is not confined only to the surface of the skin. In humans, no cell is more than 0.1 mm away from a capillary that transports blood to bring nutrients and remove wastes.

Plants also have transport systems for essential materials. These are different from the systems in animals. The **xylem** is concerned with the delivery of water from the roots to all parts of the plant while the **phloem** distributes sugars throughout the plant according to conditions operating at any particular time. The transport systems may carry substances long distances, up to 100 m in large trees.

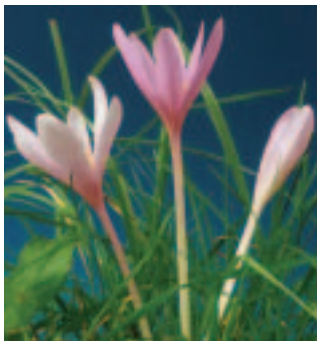


FIGURE C2.29 Despite size differences the two plants must use similar processes to supply their cells with nutrients and remove wastes.

reSEARCH

Investigate the range of surface to volume ratios in different types of human cells and plant cells. Relate your findings to the functions of the cells. Begin your search at www.pearsoned.ca/school/science 10

Some organisms or specialized structures have features that help to increase the overall surface area to volume ratio. The alveoli in your lungs are small sacs that increase the total surface area for transport of oxygen and carbon dioxide. Tiny finger-like projections, called villi and microvilli, extend from the lining of your small intestine to provide more surface for the absorption of nutrients. The roots of plants have tiny, thin extensions called root hairs that increase the surface area of the cell available for the uptake of water.

C2.4 Check and Reflect

Knowledge

1. Define the following terms:
   a) surface area
   b) volume
   c) surface area to volume ratio

2. As a cell gets larger, how does its surface area to volume ratio change?

3. What is the limiting factor when it comes to the size of a cell? Explain.

4. As the cell grows larger and increases in volume, will it need more or less cell membrane to survive? Explain.

5. How does the surface area to volume ratio of a cell affect the rate of diffusion of materials across the cell's surface?

6. What determines the size and shape of cells in multicellular organisms?

Applications

7. Assuming a spherical balloon and a cylindrical balloon both contain the same amount of air, which one would represent the more efficient cell? Explain your answer.

8. Assume that you have a perfect cube of side 4 cm.
   a) Calculate the surface area of the cube.
   b) Calculate the volume of the cube.

   Cut the cube in half so that you have two identical rectangular prisms.
   c) What is the surface area of each of the two new rectangular prisms?
   d) What is their combined surface area?
   e) What is the volume of each new piece? What is the combined volume?
   f) Describe how cutting the cube in half affects surface area, volume, and the relation between surface area and volume.

Section Review

Knowledge

1. What are the life processes necessary for an organism to survive?
2. What is the function of:
   a) the cell membrane?
   b) mitochondria?
   c) chloroplasts?
3. Name the four major types of organic compounds found in the cell and give examples of each.
4. Draw a diagram of the cell membrane to show the arrangement of the phospholipid bilayer.
5. List the four points of the particle theory.
6. Define the term "semi-permeable."
7. Describe the differences between the following terms when comparing concentrations in solutions:
   a) isotonic
   b) hypotonic
   c) hypertonic
8. What factor determines whether or not transport across the cell membrane is "active" or "passive"?
9. Describe similarities and differences in the processes of diffusion, facilitated diffusion, and active transport.
10. List two situations where a cell would use endocytosis and two situations where a cell would use exocytosis.
11. What is a hormone? Give an example.
12. What are recognition proteins? Give two examples of the operation of recognition proteins.
13. Identify a drawback to the use of liposomes for the treatment of tumours.
14. What is a scientific model? How do models assist our understanding of concepts? Give an example.
15. Distinguish between surface area, volume, and surface area to volume ratio. Include formulas.
16. Onion cells are rectangular prisms, not cubic or spherical. Use the information below to calculate the surface area, volume, and surface area to volume ratio of the onion cell models.

Cell #	Length (cm)	Width (cm)	Height (cm)	Surface Area *(A)*	Volume *(v)*	Surface Area to Volume Ratio *(A/v)*
1	5	3	2			
2	12	5	1			
3	40	27	20			

17. Predict which one of the models in question 16 will have the fastest rate of diffusion across the surface. Give reasons for your answer.
18. Explain how diffusion takes place, using an example.
19. What is meant by a concentration gradient?
20. A container has two compartments, A and B, separated by a permeable membrane inserted vertically through the middle. A 10 g/L NaCl solution is placed in compartment A and a 12 g/L NaCl solution is placed in compartment B.
    a) Describe the movement of particles that will occur across the membrane.
    b) Draw a diagram to illustrate the movement of particles across the membrane.
21. What is osmosis?
22. Explain the process of reverse osmosis. Contrast this with osmosis.

Applications

23. Identify each part of a plant cell. Compare the parts to the operation of a factory or to the services provided in a community. Include at least four organelles and an explanation for your choice of comparison. Choose a way to present your comparison: poster, diagram, model, electronic presentation, skit, or another format of your choice.

Section Review

24. Use a Venn diagram to illustrate the similarities and differences between plant and animal cells.

25. Explain how a cell's plasma membrane functions.

26. Identify ways in which the rate of diffusion can be changed. Explain each factor using the particle model.

27. How is peritoneal dialysis based on our understanding of the function of the cell membrane? Find out more about peritoneal dialysis and hemodialysis from the Kidney Foundation of Canada. Prepare a report.

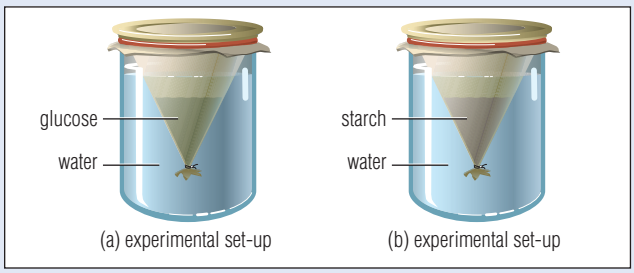
28. What is the purpose of a hypothesis in an investigation?

29. Why do grocery store owners spray fresh vegetables with water? Are there any vegetables for which this is not a good idea?

30. Describe how recognition proteins are or may be used in cancer treatment.

31. For a cell to be able to carry out the life processes, materials must be able to move in and out of the cell, as well as within the cell. What is the advantage of having a large surface area?

32. Dialysis tubing will allow small molecules like water and glucose to pass through but will prevent large molecules like starch. Examine the diagram below. Determine what will happen in each situation.



(a) Dialysis tubing containing a glucose solution placed in a beaker of water

(b) Dialysis tubing containing a starch solution placed in a beaker of water

33. Your teacher has set a challenge for the class. You must dissolve 10 g of salt in 300 mL of water in the shortest possible time. Half the class has been given coarse rock salt, while the other half has been given fine table salt.

a) Predict which half of the class will win the race.

b) Explain your answer with regard to surface area and rates of diffusion.

34. Is there anything that the students who have been given the coarse rock salt could do to increase their chance of winning? Use your knowledge of the particle model and surface area to suggest possible strategies.

Extensions

35. If the members of a shipwrecked crew drink sea water, they will probably die. Why?

36. Relate the functions of the cell membrane to the fluid-mosaic model of the membrane.

37. Design and build a model of a semi-permeable membrane.

38. Provide an analogy for facilitated diffusion. Explain how the analogy serves to represent the work of channel and carrier proteins.

39. Research other current uses of membrane technologies in industry or medicine, apart from the examples used in the text. Write a paragraph describing one of these applications.

40. Using electronic and print resources, find out about current research and breakthroughs in cancer and HIV treatments. Write a report illustrating how this research is related to our understanding of the way cells function.

41. As organisms increase in size, they have proportionately less surface area per unit volume. Find out how large organisms compensate for the small surface area to volume ratio.

42. Identify one significant thing that you learned from this section and one topic that you would like to know more about.

43. Why would enormous insects, often seen in science fiction movies, be unlikely to survive in our present-day environment?